XIXth Workshop on High Energy Spin Physics dedicated to 90th anniversary of A.V. Efremov birth

“Exclusive reactions and Spin problems at SPD”

S.S. Shimanskiy (JINR)

E. Leader, Spin in Particle Physics
© Cambridge University Press, 2001

p.Xiv

“Spin plays a dramatic Jekyll and Hyde role in the theatre of elementary particle physics, acting sometimes as the harbinger of the demise of a current theory, sometimes as a powerful tool in the confirmation and verification of such a theory”.

“Спин играет драматическую роль Джекилл и Хайда в театре физики элементарных частиц, иногда выступая в качестве предвестника упадка существующей теории, а иногда, выступая в качестве мощного орудия проверки и подтверждения такой теории”.

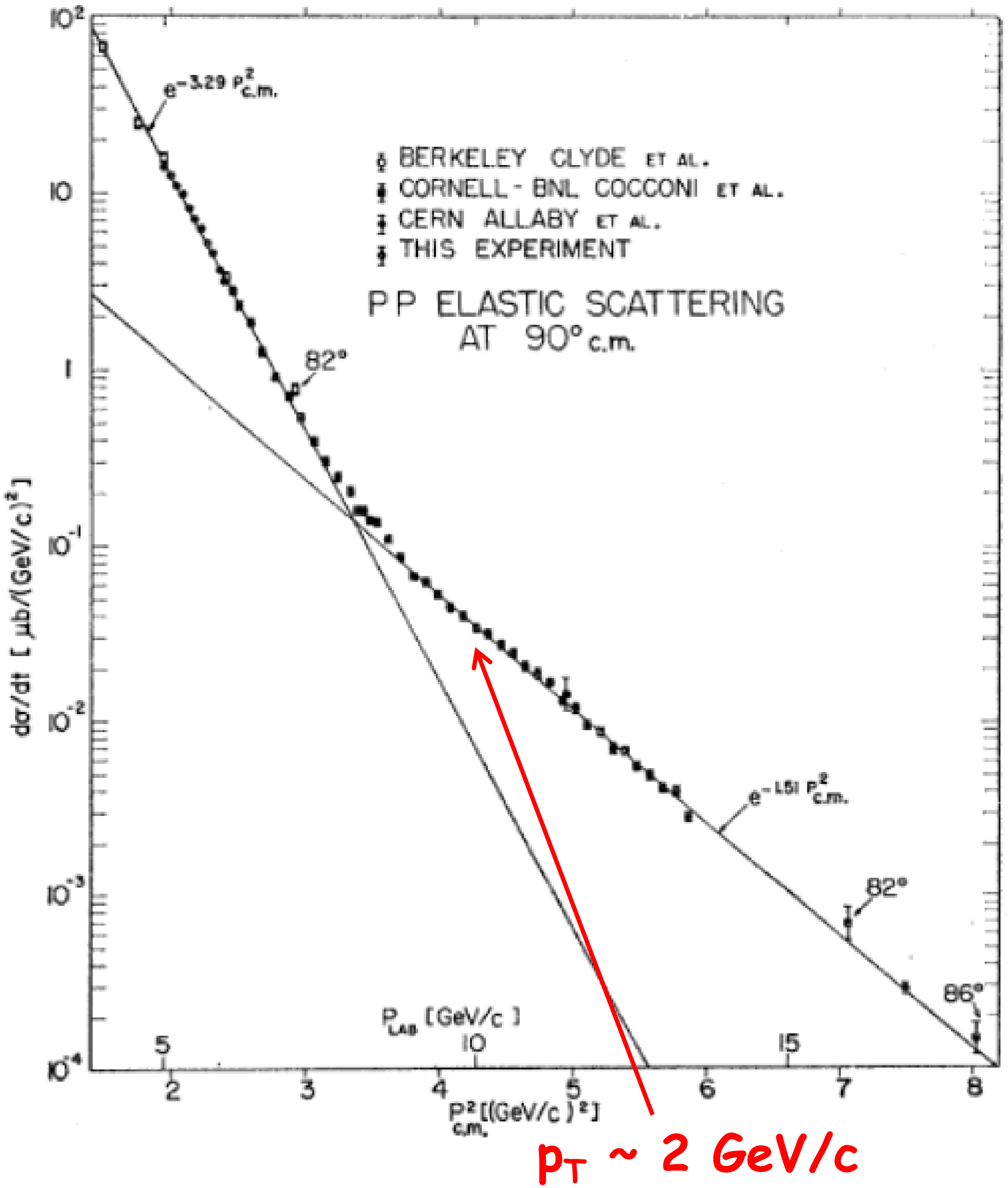
Plan

1. Which Spin and other problems at NICA energies are interesting to study at high p_T range?

2. How we could make discoveries.

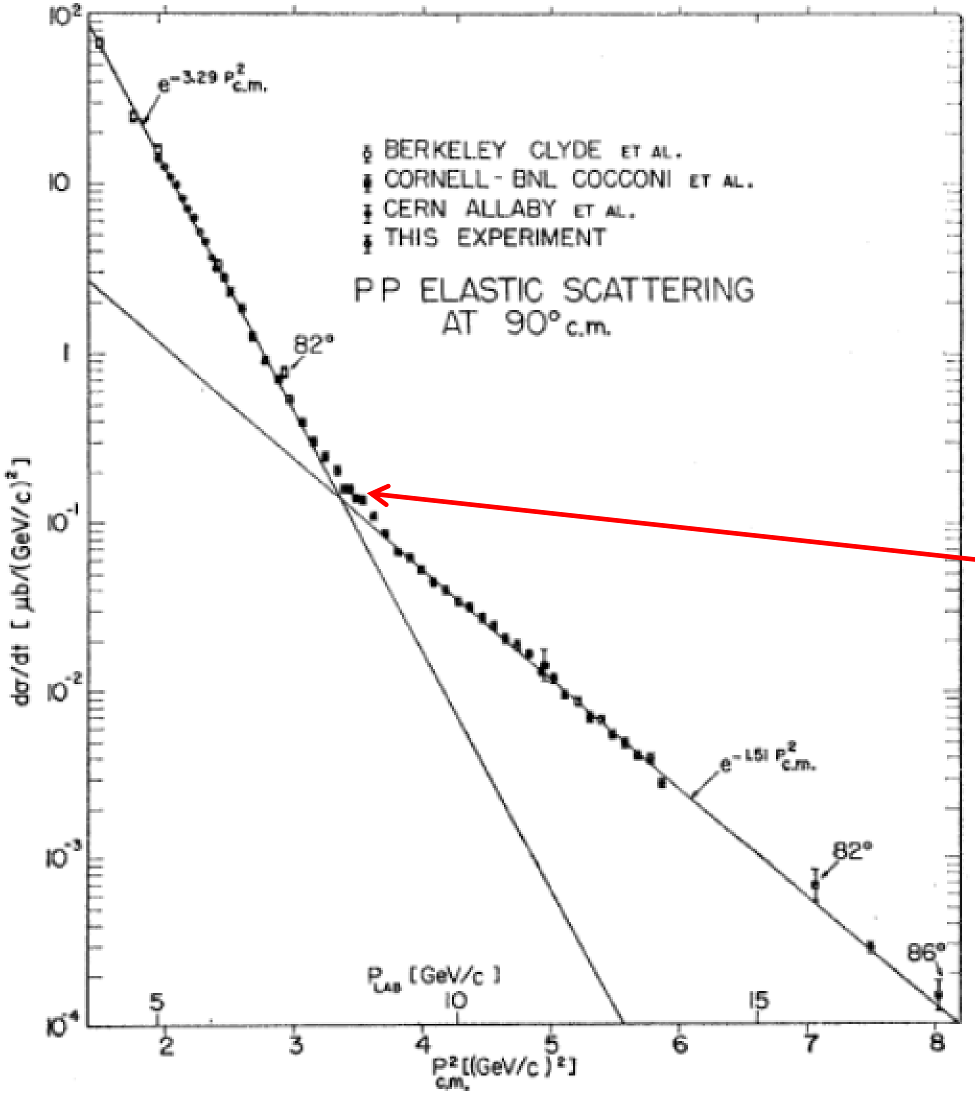
Non polarized processes and problems

C.W. Akerlof et al., Phys.Rev., vol.159, N5, 1138-1149, 1967



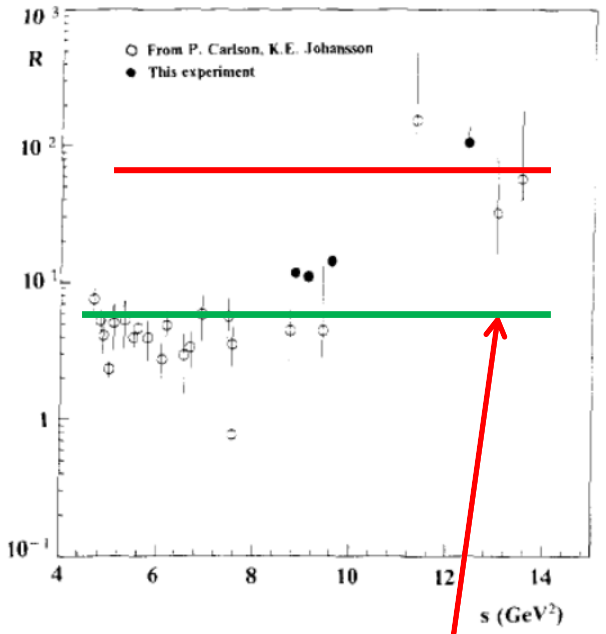
pp -> pp (90^0)

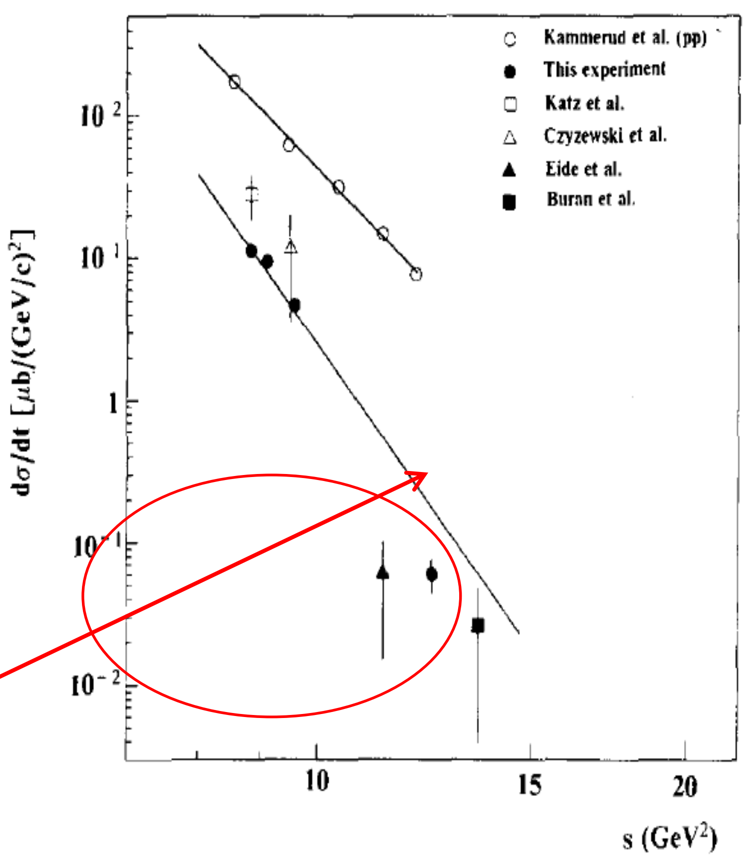
C.W. Akerlof et al., Phys.Rev., vol.159, N5, 1138-1149, 1967



Krisch A. and Leksin G. – Substructure of nucleon

$p_T \sim 2$ GeV/c





$$R = \frac{\sigma(pp \to pp)}{\sigma(\bar{p}p \to \bar{p}p)} (90^o \, c.m.)$$

p_T ~ 2 GeV/c region

C. Baglin et al., Phys.Lett. B, vol.225, N3, 296-300, 1989

Fig. 3. The pp̄ and pp elastic differential cross sections at 90° CM as function of the square of the CM energy, s. Open circles are pp data from ref. [6]. These data fit well to the drawn curve proportional to s^{-9}. The remaining points are pp̄ data. Shaded from this experiment. Otherwise from ref. [7] (open square), ref. [8] (open triangle) ref. [9] (shaded triangle) and ref. [10] (shaded square). The lower curve is an s^{-n} fit to four data points of this experiment, neglecting systematic errors. One obtains $n = 12.3 \pm 0.2$, but evidently the data do not seem to follow this kind of a power law.

КВАРКОВАЯ ЭКЗОТИКА

Volume 8, number 3 PHYSICS LETTERS 1 February 1964

Multiquark states have been discussed since the 1st page of the quark model

A SCHEMATIC MODEL OF BARYONS AND MESONS *

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Received 4 January 1964

If we assume that the strong interactions of baryons and mesons are correctly described in terms of the broken "eightfold way" [1-3], we are tempted to look for some fundamental explanation of the situation. A highly promised approach is the purely dynamical "bootstrap" model for all the strongly interacting particles within which one may try to derive isotopic spin and strangeness conservation and broken eightfold symmetry from self-consistency alone [4]. Of course, with only strong interactions, the orientation of the asymmetry in the unitary space cannot be specified; one hopes that in some way the selection of specific components of the F-spin by electromagnetism and the weak interactions determines the choice of isotopic spin and hypercharge directions.

Even if we consider the scattering amplitudes of strongly interacting particles on the mass shell only and treat the matrix elements of the weak, electromagnetic, and gravitational interactions by means of ... ber $n_t - n_{\bar{t}}$ would be zero for all known baryons and mesons. The most interesting example of such a model is one in which the triplet has spin $\frac{1}{2}$ and $z = -1$, so that the four particles d^-, s^-, u^0 and b^0 exhibit a parallel with the leptons.

A simpler and more elegant scheme can be constructed if we allow non-integral values for the charges. We can dispense entirely with the basic baryon b if we assign to the triplet t the following properties: spin $\frac{1}{2}$, $z = -\frac{1}{3}$, and baryon number $\frac{1}{3}$. We then refer to the members $u^{\frac{2}{3}}$, $d^{-\frac{1}{3}}$, and $s^{-\frac{1}{3}}$ of the triplet as "quarks" [6] q and the members of the anti-triplet as anti-quarks $\bar{q}$. Baryons can now be constructed from quarks by using the combinations (qqq), $(qqqq\bar{q})$, etc., while mesons are made out of $(q\bar{q})$, $(qq\bar{q}\bar{q})$, etc. It is assuming that the lowest baryon configuration (qqq) gives just the representations **1**, **8**, and **10** that have been observed, while the lowest meson configuration $(q\bar{q})$ similarly gives just **1** and **8**.

(dd or ud or uu)

... that it would never have been detected. A search for stable quarks of charge $-\frac{1}{3}$ or $+\frac{2}{3}$ and/or stable di-quarks of charge $-\frac{2}{3}$ or $+\frac{1}{3}$ or $+\frac{4}{3}$ at the highest energy accelerators would help to reassure us of the non-existence of real quarks.

Volume 49B, number 5 PHYSICS LETTERS 13 May 1974

ON QUARK MOLECULES

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Received 7 March 1974

The nonrelativistic quark model with three triplets and an octet of coloured gluons is examined. The interaction energy corresponding to certain quark molecules is calculated. It is shown that systems of $qq\bar{q}\bar{q}$ and $qqqq\bar{q}$ are more strongly bound than $q\bar{q}$ and qqq. Thus in order for the model to be valid there must exist exotic particles.

How Often Do Diquarks Form? A Very Simple Model

Richard F. Lebed*
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(Dated: June, 2016)

Starting from a textbook result, the nearest-neighbor distribution of particles in an ideal gas, we develop estimates for the probability with which quarks q in a mixed q, $\bar{q}$ gas are more strongly attracted to the nearest q, potentially forming a diquark, than to the nearest $\bar{q}$. Generic probabilities lie in the range of tens of percent, with values in the several percent range even under extreme assumptions favoring $q\bar{q}$ over qq attraction.

We have seen that the large relative size of the short-distance attraction between quarks in the color-antitriplet channel compared to the attraction between a quark and an antiquark in the color-singlet channel leads inexorably to a given quark being initially attracted to a quark rather than an antiquark a sizeable fraction of the time. We interpret this initial attraction as the seed event in the formation of a compact diquark qq rather than a color-singlet $q\bar{q}$ pair.

Published in: *Phys.Rev.D* 94 (2016) 3, 034039; e-Print: 1606.07108 [hep-ph]

Phys.Rev.C 83 (2011) 054606
arXiv:1007.4705v5 [hep-ph]2010
Carlos Granados and Misak Sargsian

Who can predict
nn -> nn to pp -> pp?

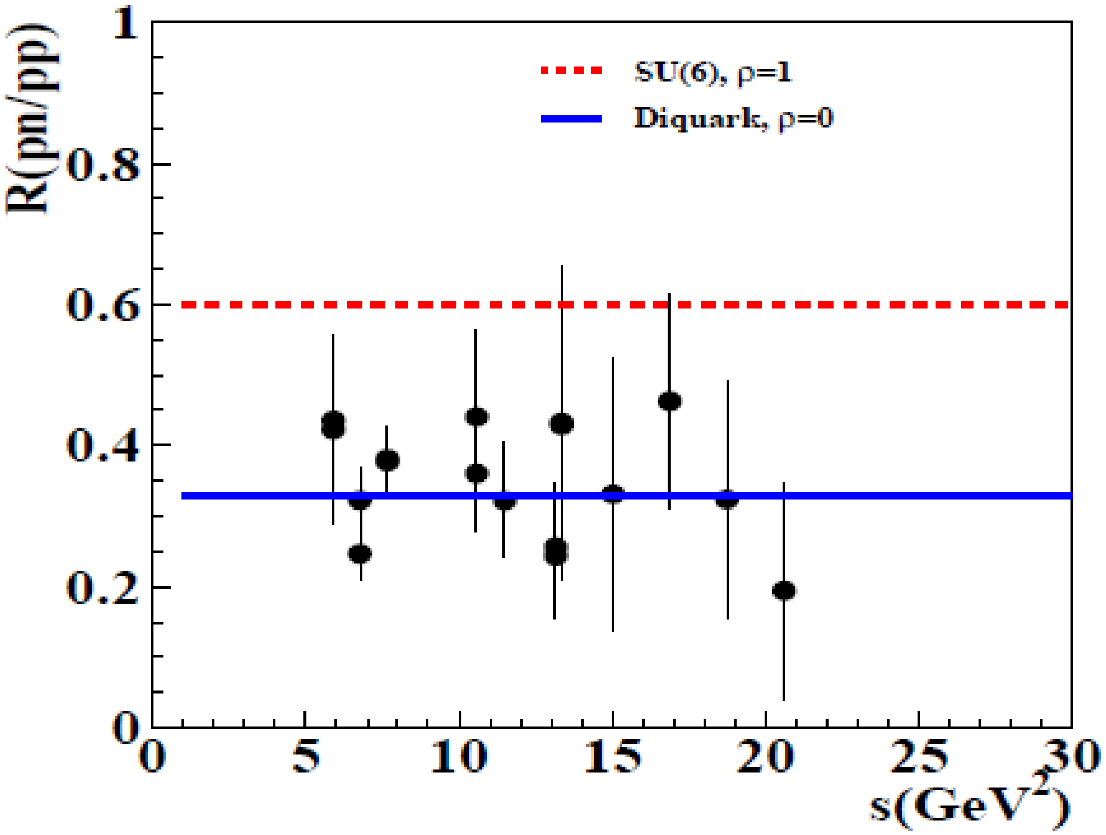

FIG. 2: (Color online) Ratio of the $pn \to pn$ to $pp \to pp$ elastic differential cross sections as a function of s at $\theta^N_{c.m.} = 90^0$.

Quark counting rules

In 1973 were published two articles :

Matveev V.A., Muradyan R.M., Tavkhelidze A.N. Lett. Nuovo Cimento 7,719 (1973);

Brodsky S., Farrar G. Phys. Rev. Lett. 31,1153 (1973)

Predictions that for momentum $p_{beam} \geq 5$ GeV/c in any binary large-angle scattering ($\theta_{cm} > 40°$) reaction at large momentum transfers $Q = \sqrt{-t}$:

$$A + B \to C + D$$

$$\frac{d\sigma}{dt}_{A+B\to C+D} \sim S^{-(n_A+n_B+n_C+n_D-2)} f\left(\frac{t}{s}\right)$$

where n_A, n_B, n_C and n_D the amounts of elementary constituents in A,B,C and D.

$s=(p_A+p_B)^2$ and $t=(p_A-p_C)^2$,

$$\frac{d\sigma}{dt}_{pp\to pp} \sim S^{-10} \quad \text{and} \quad \frac{d\sigma}{dt}_{\pi p\to \pi p} \sim S^{-8}$$

Scaling Laws at Large Transverse Momentum*

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and

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(Received 14 August 1973)

The application of simple dimensional counting to bound states of pointlike particles enables us to derive scaling laws for the asymptotic energy dependence of electromagnetic and hadronic scattering at fixed c.m. angle which only depend on the number of constituent fields of the hadrons. Assuming quark constituents, some of the $s\to\infty$, fixed-t/s predictions are $(d\sigma/dt)_{\pi p\to\pi p}\sim s^{-8}$, $(d\sigma/dt)_{pp\to pp}\sim s^{-10}$, $(d\sigma/dt)_{\gamma p\to\pi p}\sim s^{-7}$, $(d\sigma/dt)_{\gamma p\to\gamma p}\sim s^{-6}$, $F_\pi(q^2)\sim(q^2)^{-1}$, and $F_{1p}(q^2)\sim(q^2)^{-2}$. We show that such scaling laws are characteristic of renormalizable field theories satisfying certain conditions.

Our central result for exclusive scattering[1] is

$$(d\sigma/dt)_{AB\to CD}\sim s^{2-n}f(t/s) \qquad (1)$$

($s\to\infty$, t/s fixed). Here n is the total number of leptons, photons, and quark components (i.e., elementary fields) of the initial and final states. This result follows heuristically if the only physical dimensional quantities are particle masses and momenta. We begin by considering a world in which a hadron would become a collection of free quarks with equal momenta if the strong interactions were turned off. Note that the dimen-

[1]This result for elastic scattering has been obtained independently by V. Matveev, R. Muradyan, and A. Tavkhelidze, Joint Institute for Nuclear Research Report No. D2-7110, 1973 (to be published). We thank J. Kiskis for bringing this work to our attention.

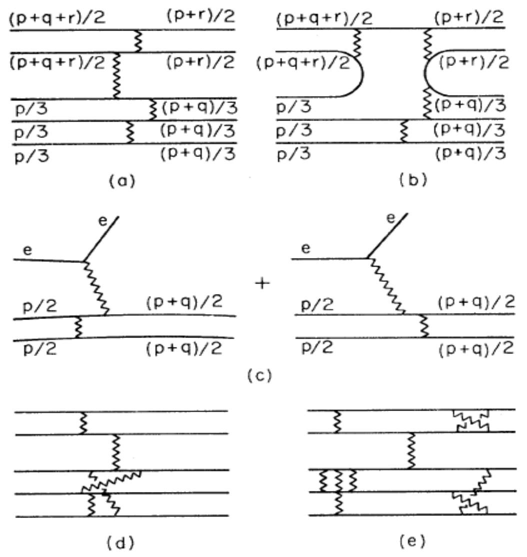


FIG. 1. Typical Born diagrams for large-momentum-transfer elastic scattering in the quark picture. (a) $\pi p\to\pi p$ (quark scattering), (b) $\pi p\to\pi p$ (quark interchange), (c) $e\pi\to e\pi$, (d) an irreducible loop diagram, (e) a reducible loop diagram.

PHYSICAL REVIEW D VOLUME 49, NUMBER 1 1 JANUARY 1994

Comparison of 20 exclusive reactions at large t

C. White,[4,*] R. Appel,[1,5,†] D. S. Barton,[1] G. Bunce,[1] A. S. Carroll,[1]
H. Courant,[4] G. Fang,[4,‡] S. Gushue,[1] K. J. Heller,[4] S. Heppelmann,[2]
K. Johns,[4,§] M. Kmit,[1,||] D. I. Lowenstein,[1] X. Ma,[3] Y. I. Makdisi,[1]
M. L. Marshak,[4] J. J. Russell,[3]
and M. Shupe[4,§]

TABLE IV. Cross sections at 90 degrees and 5.9 GeV/c incident beam momentum. Reaction number refers to Fig. 27. The values represent interpolations where the range spans 90°.

Number	Reaction	Cross section [nb/(GeV/c)^2]
1	$\pi^+ p \to p\pi^+$	132 ± 10
2	$\pi^- p \to p\pi^-$	73 ± 5
3	$K^+ p \to pK^+$	219 ± 30
4	$K^- p \to pK^-$	18 ± 6
5	$\pi^+ p \to p\rho^+$	214 ± 30
6	$\pi^- p \to p\rho^-$	99 ± 13
7	$K^+ p \to pK^{*+}$	$291 + 47 - 130$
8	$K^- p \to pK^{*-}$	$15 + 10 - 13$
9	$K^- p \to \pi^- \Sigma^+$	50 ± 21
10	$K^- p \to \pi^+ \Sigma^-$	4 ± 3
11	$K^- p \to \Lambda \pi^0$	< 80
12	$\pi^- p \to \Lambda K^0$	< 5
13	$\pi^+ p \to \pi^+ \Delta^+$	45 ± 10
14	$\pi^- p \to \pi^- \Delta^+$	20 ± 11
15	$\pi^- p \to \pi^+ \Delta^-$	24 ± 5
16	$K^+ p \to K^+ \Delta^+$	< 230
17	$pp \to pp$	3300 ± 40
18	$\bar{p}p \to p\bar{p}$	75 ± 8
19	$\bar{p}p \to \pi^+\pi^-$	7 ± 3
20	$\bar{p}p \to K^+K^-$	2 ± 2

TABLE V. The scaling between E755 and E838 has been measured for eight meson-baryon and 2 baryon-baryon interactions at $\theta_{\mathrm{c.m.}} = 90°$. The nominal beam momentum was 5.9 GeV/c and 9.9 GeV/c for E838 and E755, respectively. There is also an overall systematic error of $\Delta n_{\mathrm{syst}} = \pm 0.3$ from systematic errors of ±13% for E838 and ±9% for E755.

		Cross section		n-2
No.	Interaction	E838	E755	($\frac{d\sigma}{dt} \sim 1/s^{n-2}$)
1	$\pi^+ p \to p\pi^+$	132 ± 10	4.6 ± 0.3	6.7 ± 0.2
2	$\pi^- p \to p\pi^-$	73 ± 5	1.7 ± 0.2	7.5 ± 0.3
3	$K^+ p \to pK^+$	219 ± 30	3.4 ± 1.4	$8.3^{+0.6}_{-1.0}$
4	$K^- p \to pK^-$	18 ± 6	0.9 ± 0.9	≥ 3.9
5	$\pi^+ p \to p\rho^+$	214 ± 30	3.4 ± 0.7	8.3 ± 0.5
6	$\pi^- p \to p\rho^-$	99 ± 13	1.3 ± 0.6	8.7 ± 1.0
13	$\pi^+ p \to \pi^+ \Delta^+$	45 ± 10	2.0 ± 0.6	6.2 ± 0.8
15	$\pi^- p \to \pi^+ \Delta^-$	24 ± 5	≤ 0.12	≥ 10.1
17	$pp \to pp$	3300 ± 40	48 ± 5	9.1 ± 0.2
18	$\bar{p}p \to p\bar{p}$	75 ± 8	≤ 2.1	≥ 7.5

SLAC – PUB – 4749
October 1988
(M)

ANTIPROTON ANNIHILATION IN QUANTUM CHROMODYNAMICS*

STANLEY J. BRODSKY

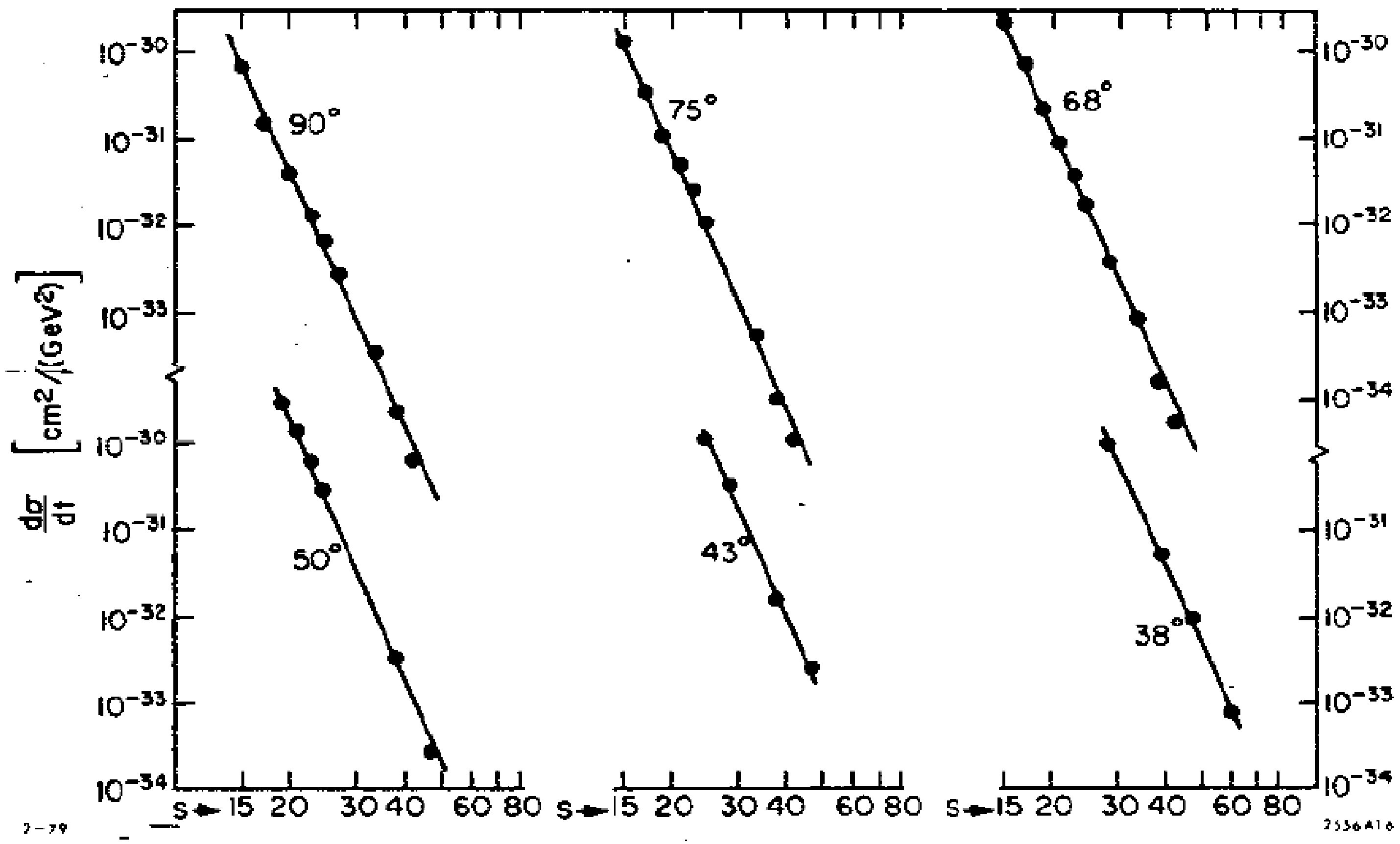


Fig. 16. Test of fixed θ_{CM} scaling for elastic pp scattering. The best fit gives the power $N = 9.7 \pm 0.5$ compared to the dimensional counting prediction $N=10$. Small deviations are not readily apparent on this log-log plot. The compilation is from Landshoff and Polkinghorne.

… + Spin ?

Soft Perturbative QCD*

Paul Hoyer

NORDITA-1999/52 HE
hep-ph/9908501
August 30, 1999

The way the differential large angle $2 \to 2$ particle scattering cross sections should scale with energy (momentum transfer) was envisaged by the so-called "quark counting rules" [26].

$$\frac{d\sigma}{dt} = \frac{f(\Theta)}{s^{K-2}}; \qquad \frac{t}{s} = \text{const},$$

with K the number of *elementary fields* (quarks, photons, leptons, etc.) among / inside the initial and final particles.

For example, in the case of the deuteron break-up by a photon, $\gamma + D \to p + n$, we have $K = 1 + 6 + 6 = 13$ (a photon and 6 quarks inside the initial deuteron and another 6 in the final proton and neutron). So, the differential cross section is expected to fall with s, *asymptotically*, as $s^{-11} = E_{\rm c.m.}^{-22}$.

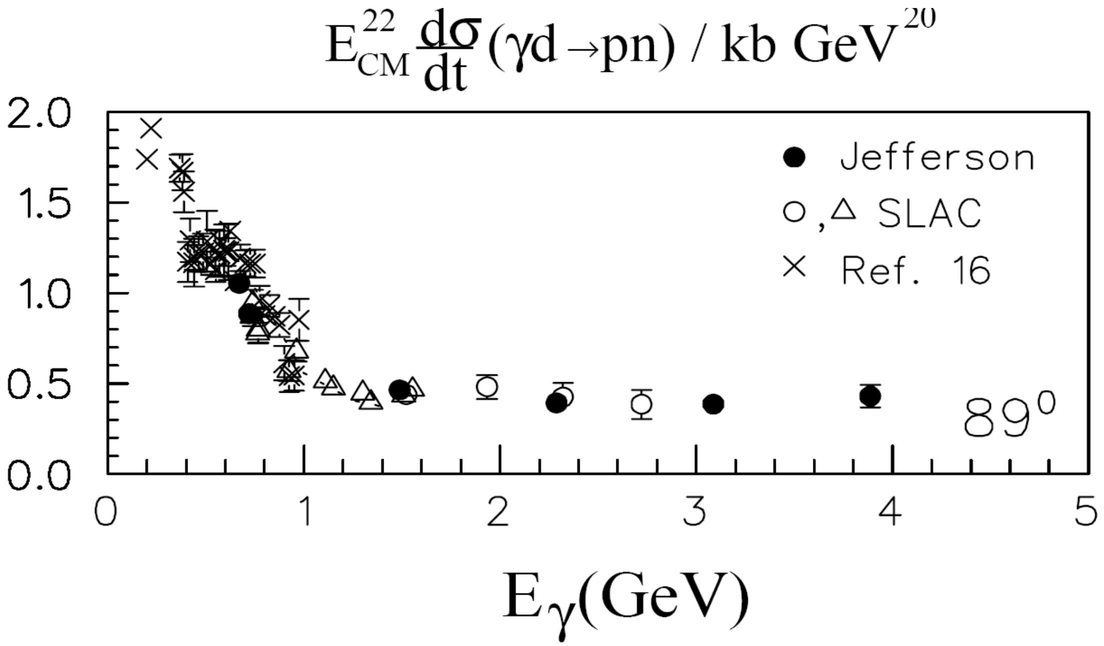
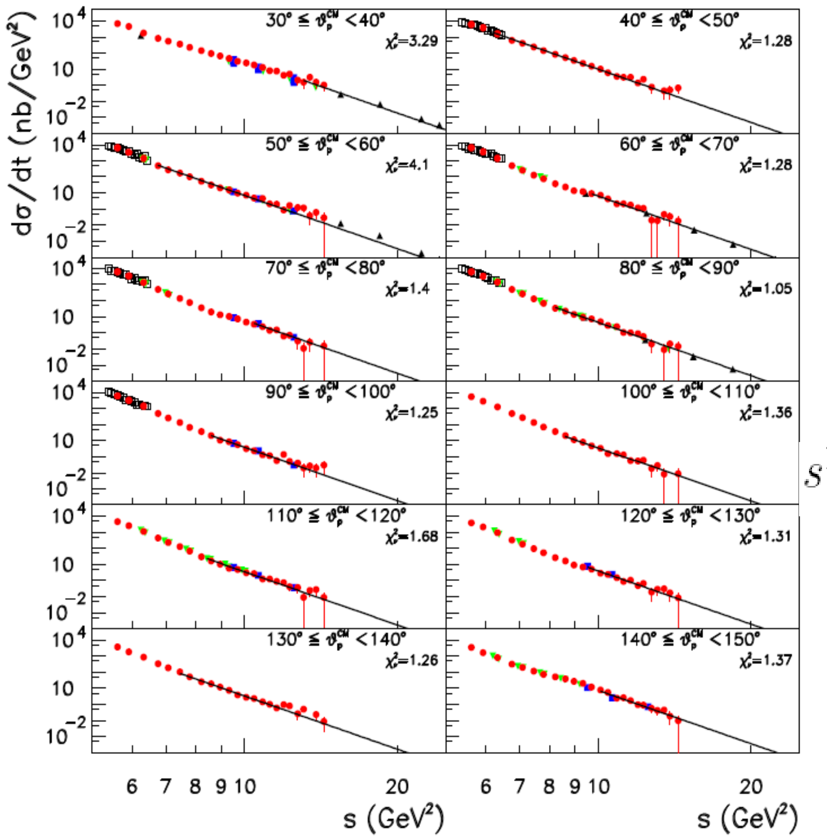


FIG. 2. The $\gamma d \to pn$ cross section at 89° multiplied by E_{CM}^{22} as a function of the photon beam energy [3].



$s^{11}\frac{d\sigma}{dt}(\gamma d \to pn) \sim$ constant at fixed CM angle

Figure 8: Fits of the cross sections $d\sigma/dt$ to s^{-11} for $P_T \geq P_T^{th}$ and proton angles between 30° and 150° (solid lines). Data are from CLAS (full/red circles), Mainz(open/black squares), SLAC (full-down/green triangles), JLab Hall A (full/blue squares) and Hall C (full-up/black triangles). Also shown in each panel is the χ^2_ν value of the fit. From Ref. [160].

Eur. Phys. J. A 8, 423–428 (2000)

THE EUROPEAN PHYSICAL JOURNAL A

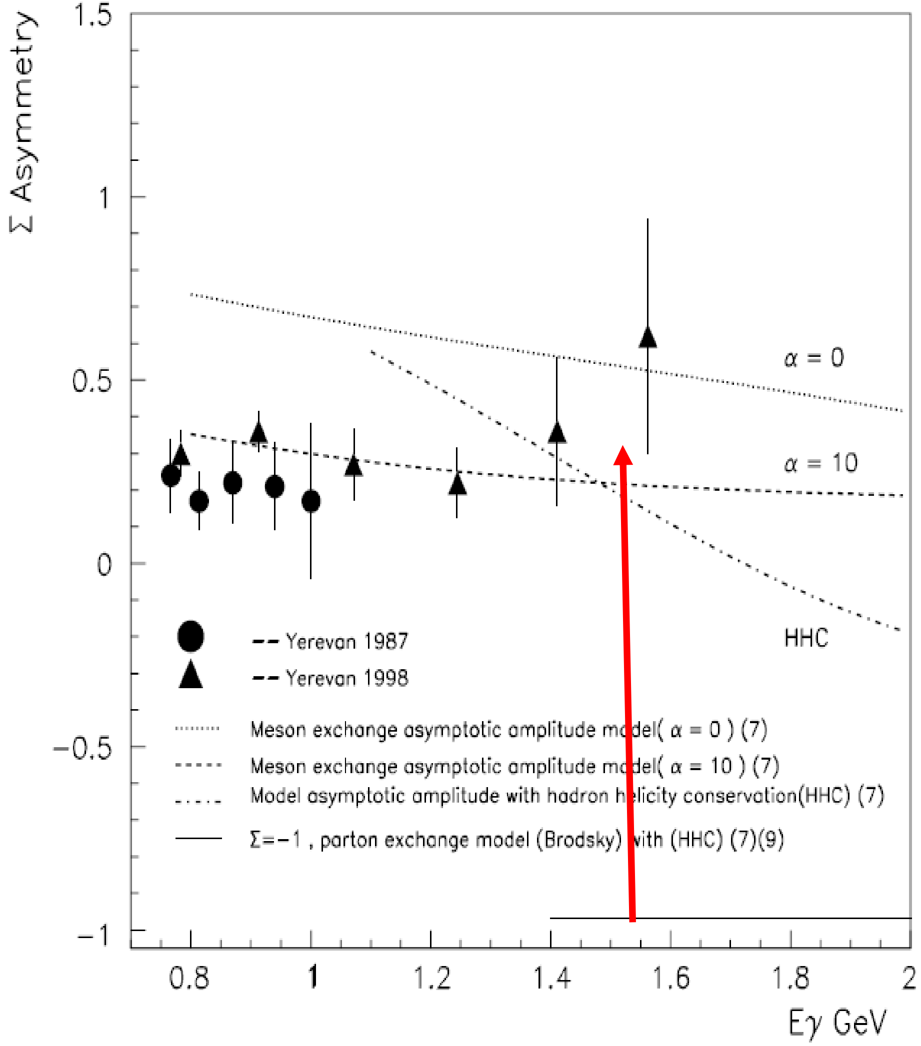


Fig. 8. The energy dependence of the cross-section asymmetry Σ for $\theta_p = 90°$ in the cms.

Measurement of the cross-section asymmetry of deuteron photodisintegration process by linearly polarized photons in the energy range $E_\gamma = 0.8$–1.6 GeV

F. Adamian[1], A. Aganiants[1], Yu. Borzunov[2], S. Chumakov[2], N. Demekhina[1], G. Frangulian[1], L. Golovanov[2], V. Grabski[1,a], A. Hairapetian[1], H. Hakobyan[1], I. Keropian[1], I. Lebedev[1], Zh. Manukian[1], N. Moroz[2], G. Movsesian[1], E. Muradian[1], A. Oganesian[1], R. Oganezov[1], Yu. Panebratsev[2], M. Rekalo[3], S. Shimanski[2], A. Sirunian[1], H. Torosian[1], A. Tsvenev[2], H. Vartapetian[1], and V. Volchinski[1]

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[3] Kharkov Institute of Physics and Technology, Kharkov, Ukraine

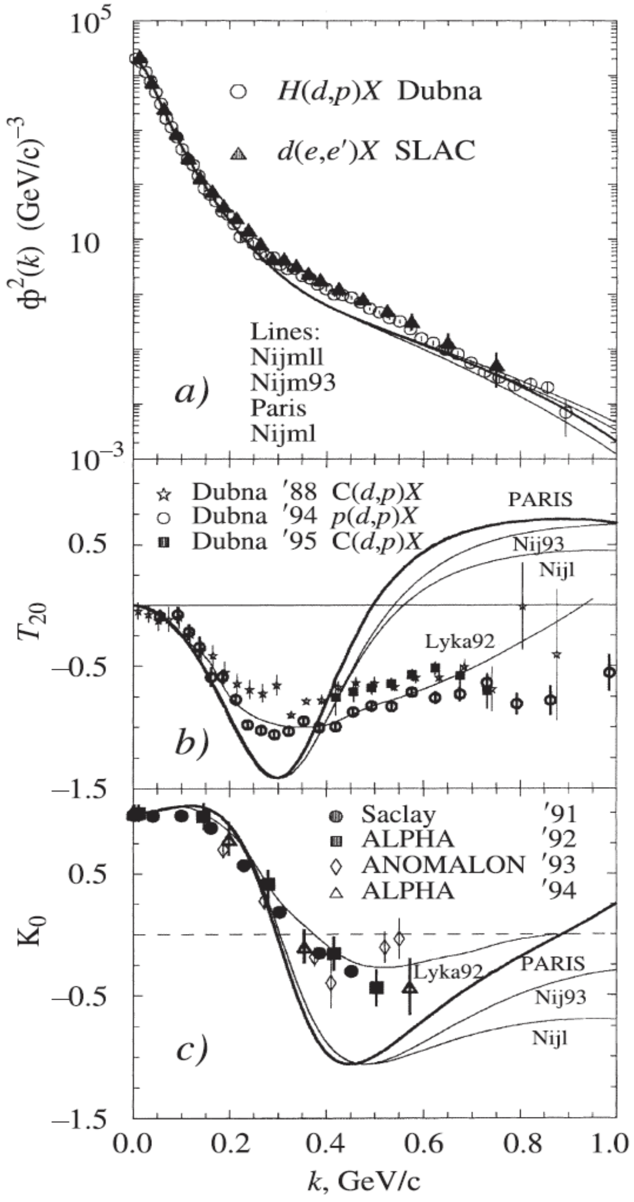
$$\Sigma = (N_n \rightarrow -N_n \uparrow)/(\bar{P}_\gamma \uparrow N_n \rightarrow +\bar{P}_\gamma \rightarrow N_n \uparrow)$$

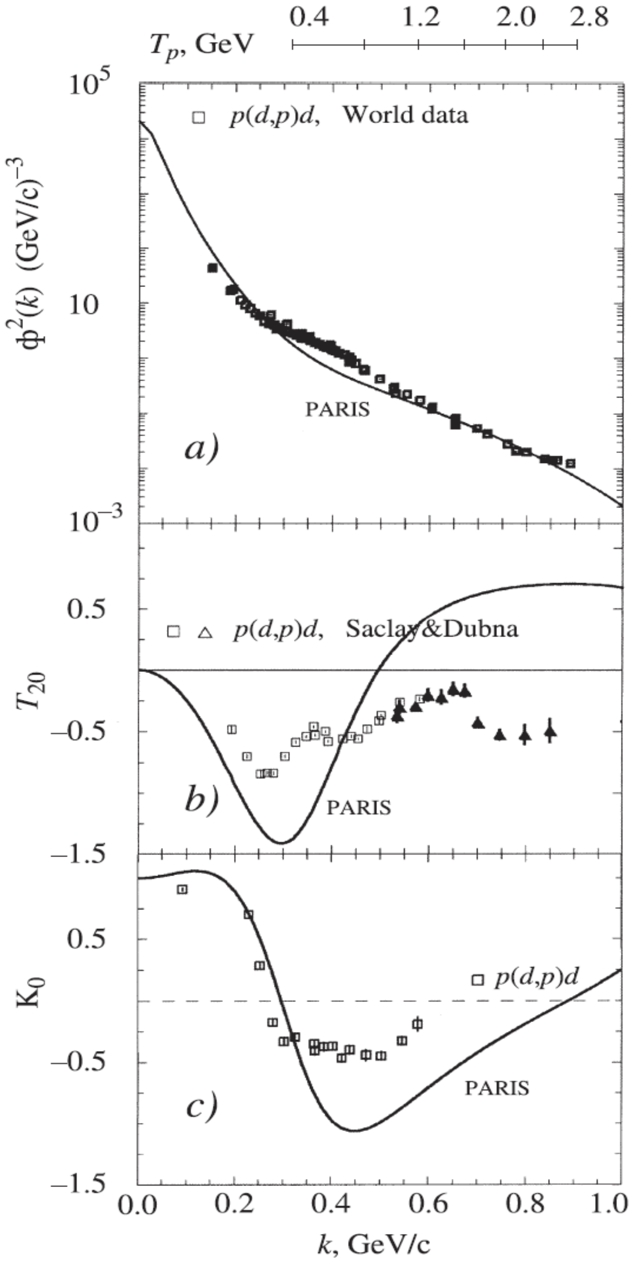
CURRENT EXPERIMENTS USING POLARIZED BEAMS OF THE JINR VBLHE ACCELERATOR COMPLEX

F. Lehar

DAPNIA, CEA/Saclay, Gif-sur-Yvette Cedex, France

Fiz. Elem. Chast. At. Yadra. 2005. V. 36. P. 954





Spin problems

SPIN IN PARTICLE PHYSICS

ELLIOT LEADER
Imperial College, London

Preface

In purely hadronic physics, too, there are tantalizing questions regarding spin dependence. There exists a whole array of semi-inclusive experiments like pp —► πX with a transversely polarized proton beam or target, or pp —► hyperon + X, with an unpolarized initial state in which huge hyperon spin asymmetries or polarizations — at the 30%-40% level! — are observed. These experiments are very hard to explain within the framework of QCD. The asymmetries all vanish at the partonic level and one has to invoke soft, non-perturbative mechanisms. All such mechanisms predict that the asymmetries must die out as the momentum transfer increases, yet there is no sign in the present data of such a decrease.

In exclusive reactions like pp —► pp the disagreement between the data on the analysing power at large momentum transfer and the naive QCD asymptotic predictions is even more severe, but here at least there is an escape clause: the theory of exclusive reactions in QCD is horrendously difficult.

A. Krisch, 28.02.2010 LHEP Seminar

SUMMARY

For the past 30 years QCD-based calculations have continued to disagree with the ZGS 2-spin & AGS 1-spin elastic data and the ZGS, AGS, Fermilab & RHIC inclusive data.

* These large spin effects do not go to zero at high-energy or high-$P_\perp$ as was predicted.
* No QCD-based model can explain all the large spin effects.

BASIC PRINCIPLE OF SCIENCE:

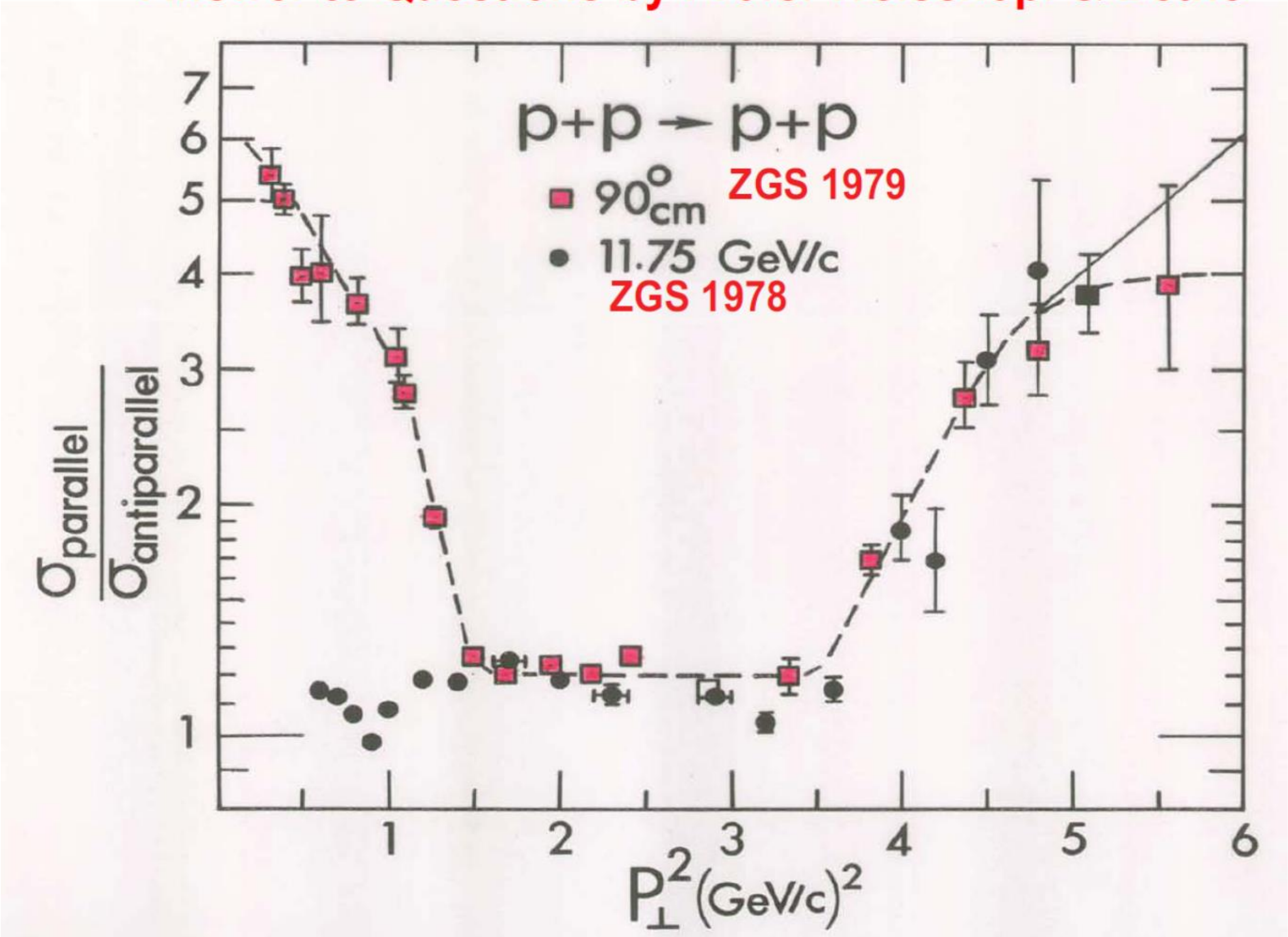
If a theory does not agree with reproducible experimental data, then the theory must be modified.

These precise spin experiments provide experimental guidance for the required modification of the theory of Strong Interactions.

Elastic $d\sigma/dt$, A_{nn} and A_n experiments at higher energy and $P_\perp$ could provide more guidance, just as the RHIC inclusive A_n experiments confirmed the similar Fermilab experiments. (E-704 Yokosawa et al.).

NICA energy range?

Answer to Questions by Profs. Weisskopf & Bethe



AGS 1985-1990 A_n

PERTURBATIVE QCD ⇒

A_n = 0 at HIGH $P_\perp^2$ and HIGH ENERGY

$A_n \neq 0$ ⇒

PROBLEM with PQCD?

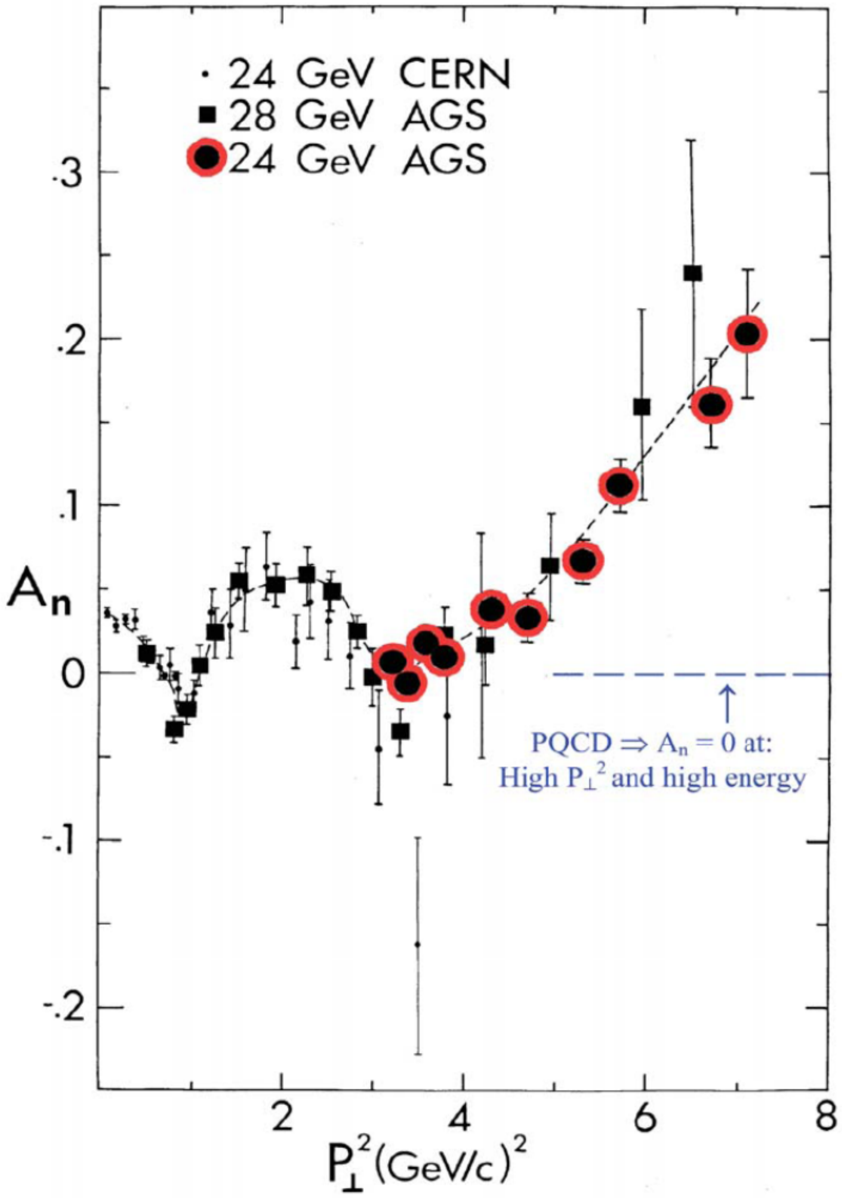
NO MODEL can EXPLAIN ALL

HIGH-$P_\perp^2$ SPIN EFFECTS (A_n & A_{nn})

GOAL

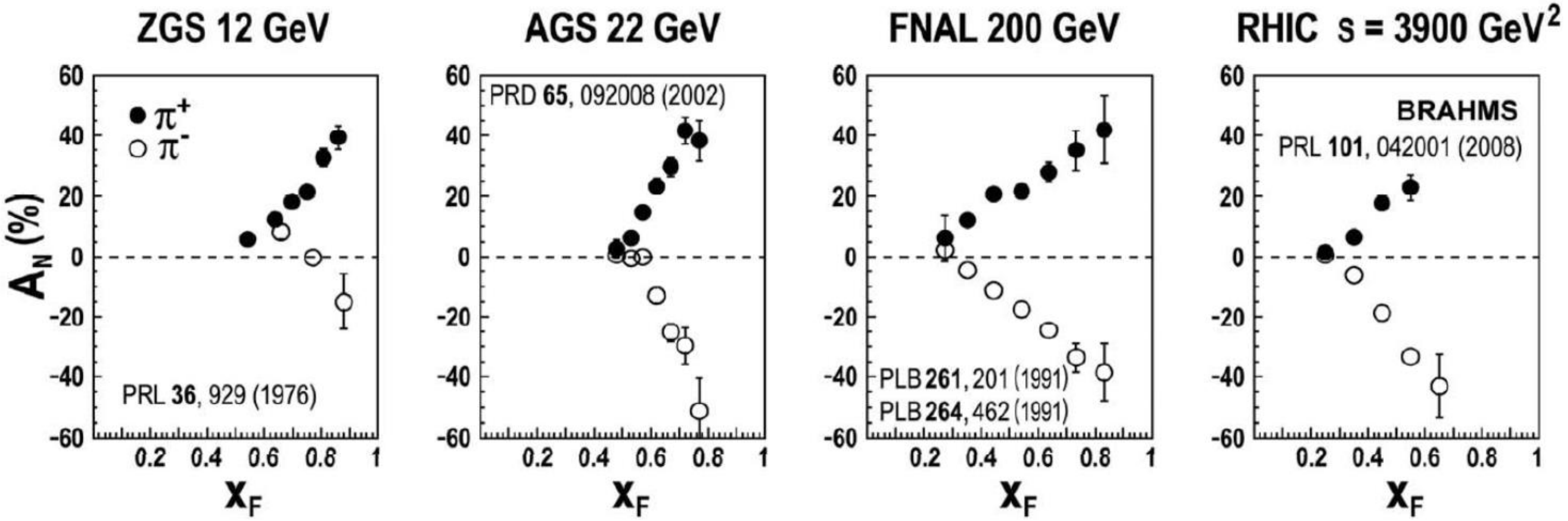
MEASURE A_n (and A_{nn})

up to $P_\perp^2$ = 12 (GeV/c)



INCLUSIVE PION ASYMMETRY IN PROTON-PROTON COLLISIONS

C. Aidala SPIN 2008 Proceeding and CERN Courier June 2009



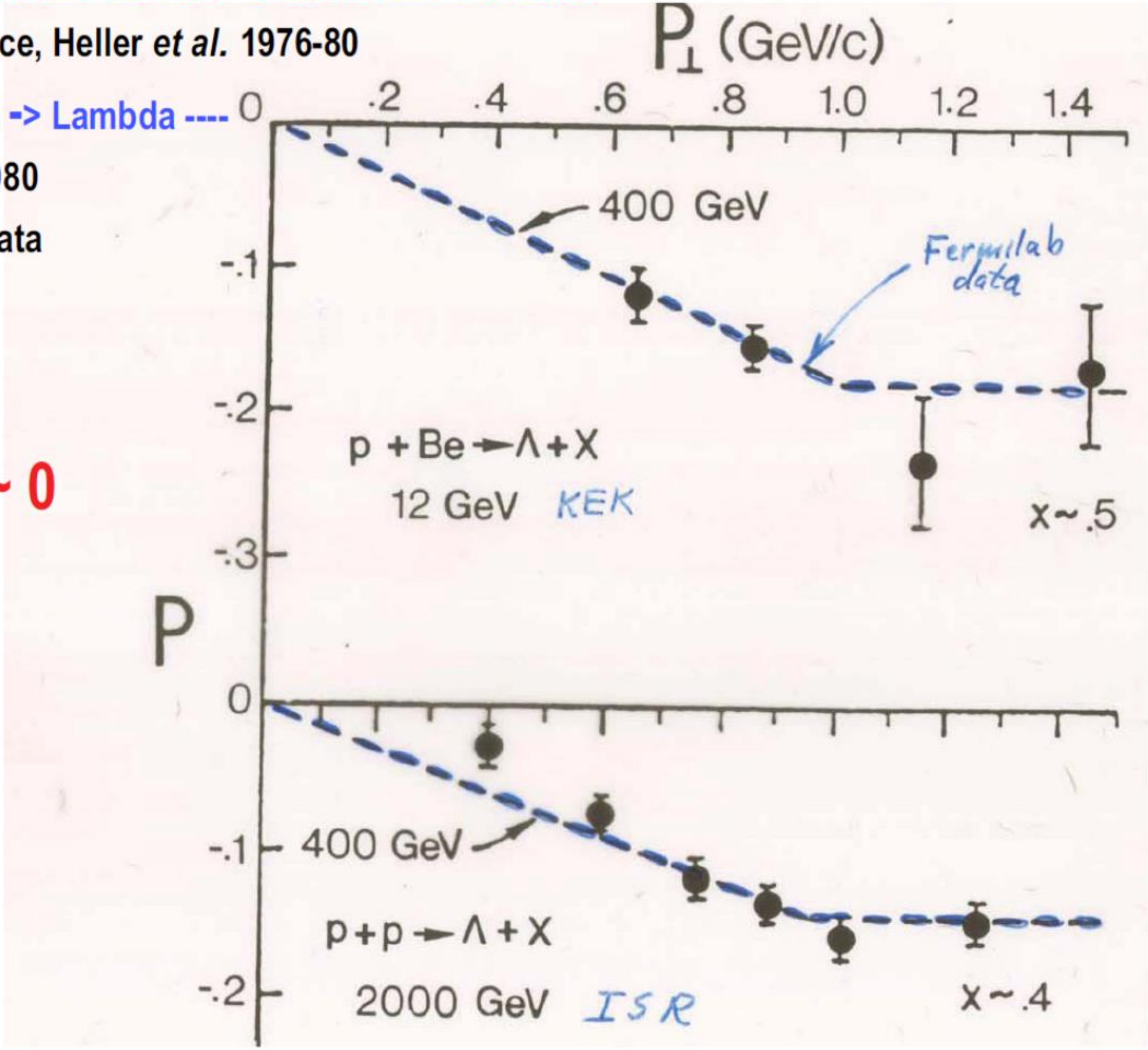
INCLUSIVE HYPERON POLARIZATION

Devlin, Pondrum, Bunce, Heller *et al.* 1976-80

Fermilab 400 GeV p+p -> Lambda ----

Plot by Heller ~1980

with KEK & ISR data



P ~ 15-20 %

QCD says P ~ 0

Spin-Spin Forces in 6-GeV/c Neutron-Proton Elastic Scattering

D. G. Crabb, P. H. Hansen, A. D. Krisch, T. Shima, and K. M. Terwilliger
Randall Laboratory of Physics, The University of Michigan, Ann Arbor, Michigan 48109
and

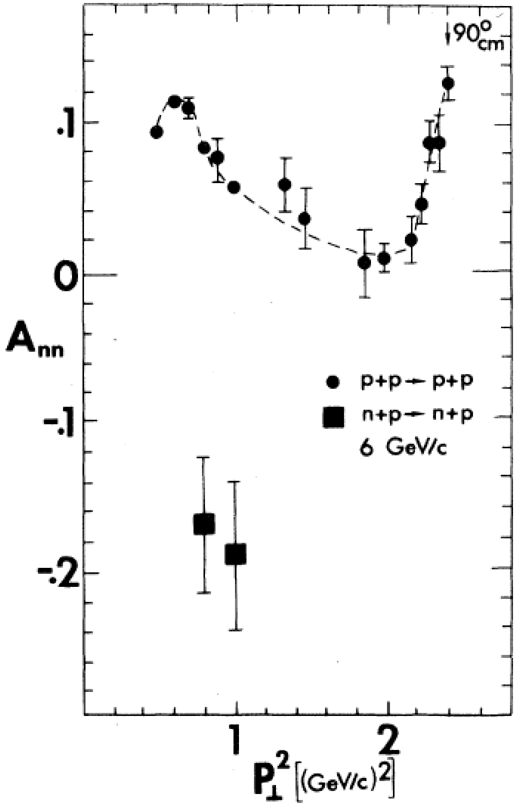


FIG. 2. The spin-spin correlation parameter, A_{nn}, for pure-initial-spin-state nucleon-nucleon elastic scattering at 6 GeV/c is plotted against the square of the transverse momentum. The proton-proton and neutron-proton data are quite different.

This large negative A_{nn} for n-p elastic scattering is quite unexpected. No theoretical models predicted this effect, although a very recent constituent-interchange model[12] predicts $A_{nn} = -44\%$. This may support the suggestion that large spin effects are related to the composite nature of the nucleon.[12,13] An earlier Regge-model prediction[14] is inconsistent with our data. It seems somewhat surprising that A_{nn} is so large at a $P_\perp^2$ of only 1 (GeV/c)^2.

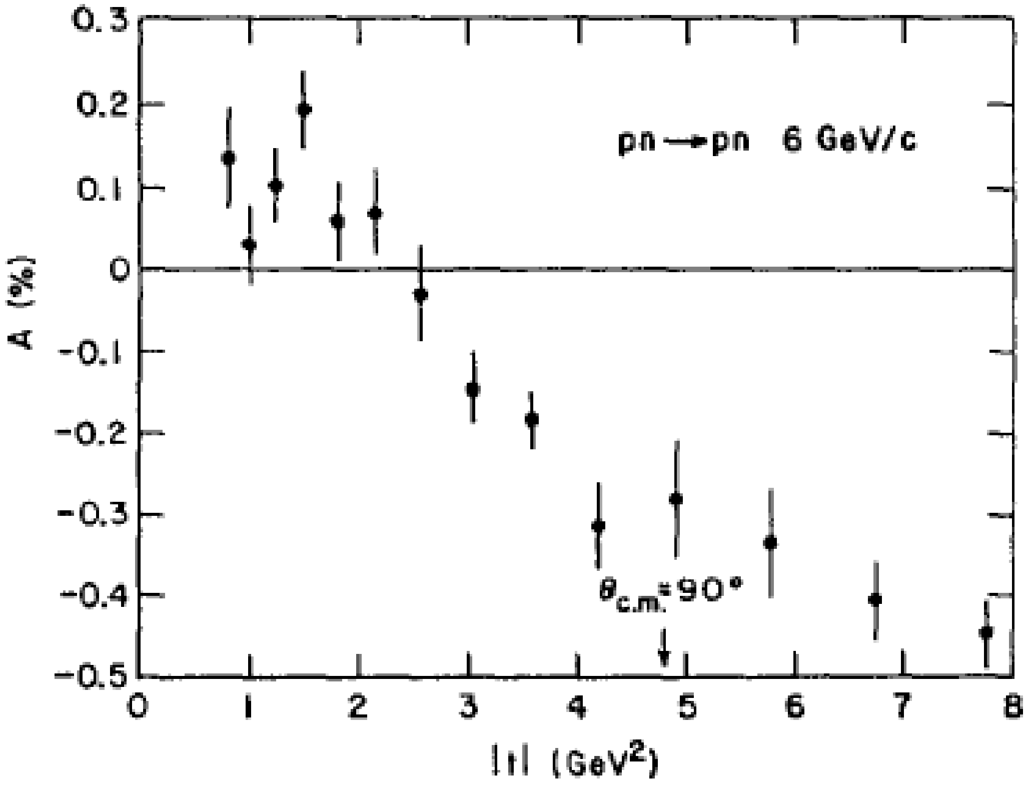
[12]G. R. Farrar, S. Gottlieb, D. Sivers, and G. H. Thomas, Phys. Rev. D 20, 202 (1979).

Nuclear Physics B279 (1987) 97 - 118
North-Holland, Amsterdam

SPIN EFFECTS IN HADRONIC REACTIONS

J. SOFFER

Fig. 1 - The analyzing power A for np elastic scattering at 6 GeV/c (taken from Ref. 5)



Unfortunately the energy is too low to draw definite conclusions on the nature of this effect and hopefully it will be remeasured at higher energies with the polarized proton beam on a deuterium target at BNL.

New detectors –> new capabilities

“New directions in science are launched by new tools much more often than by new concepts.

Новые направления в науке запускаются новыми инструментами(методиками) гораздо чаще, чем новыми концепциями.

The effect of a concept-driven revolution is to explain old things in new ways.

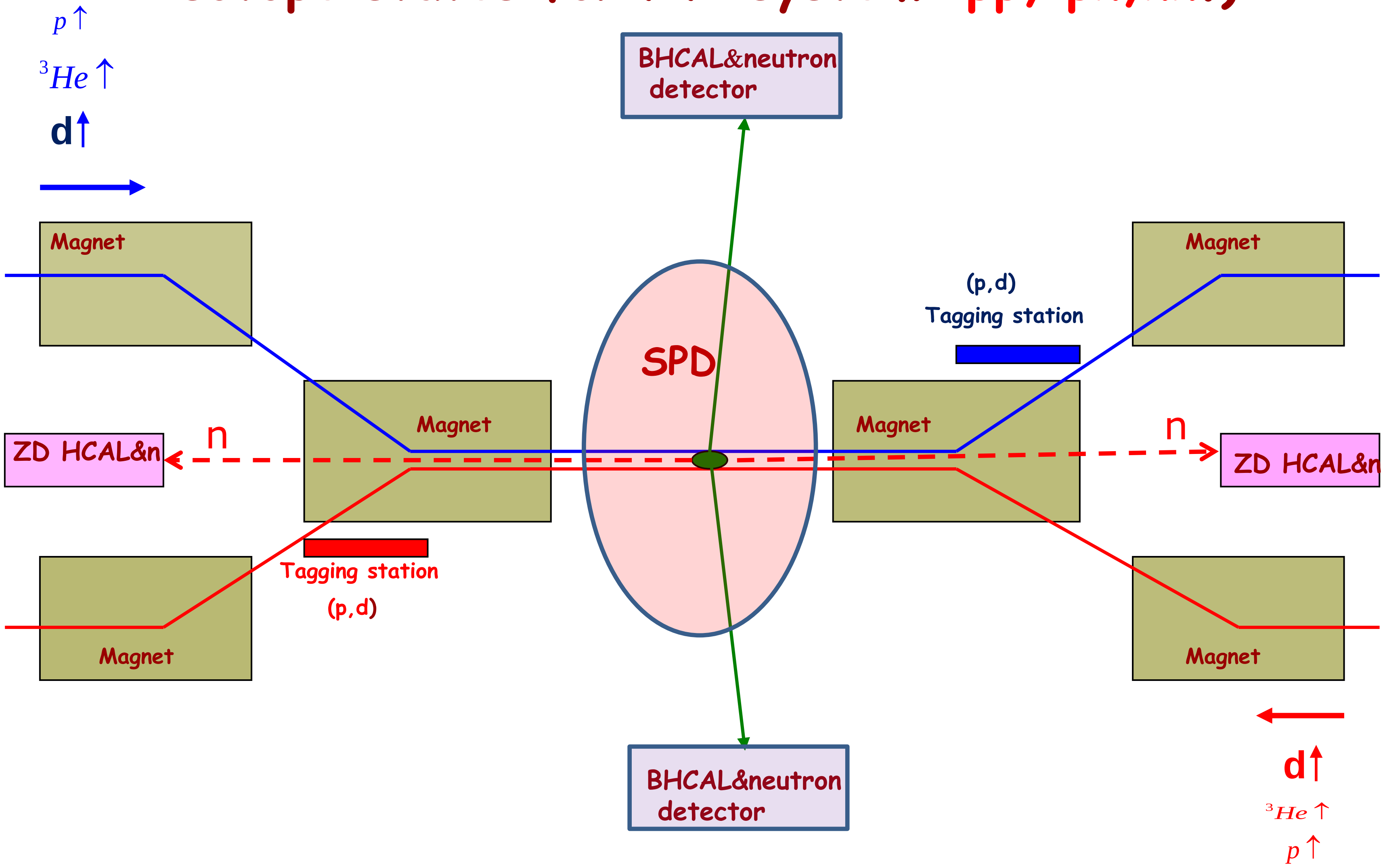
Эффект концептуальной революции состоит в том, чтобы объяснить старые вещи по-новому.

The effect of a tool-driven revolution is to discover new things that have to be explained”

Эффект инструментальной революции заключается в открытии новых вещей, которые должны быть объяснены.

From Freeman Dyson ‘Imagined Worlds’

NICA Collision place for SPIN physics (deuteron and other beams, the first time all isotope states for NN system: pp, pn,nn.)



The tagging stations can be used as polarimeter!

Some unique features for NICA

Working with spin-flippers at NICA

a) new ring fill modes (all bunches with the same polarization in both rings) and the operation (sequential switching-on of the spin-flippers in the rings):

1st ring	+++...	|xxx|	- - -...	|----|	- - -...	|xxx|	+++	|----|	+++...
2nd ring	+++...	|----|	+++...	|xxx|	- - -...	|----|	- - -	|xxx|	+++...
	(+ +)		(- +)		(- -)		(+ -)		(+ +)

|xxx| - spin-flipper switching-on, no data taking

|----| - spin-flipper switching-off, no data taking

b) there are no problem with measurement of the bunch 2 bunch luminosity and no problem to reverse the polarization at the ion source during ring fillings!

ISSN 1547-4771, Physics of Particles and Nuclei Letters, 2009, Vol. 6, No. 1, pp. 48–58. © Pleiades Publishing, Ltd., 2009.
Original Russian Text © S. Vokal, A.D. Kovalenko, A.M. Kondratenko, M.A. Kondratenko, V.A. Mikhailov, Yu.N. Filatov, S.S. Shimanskii, 2009, published in Pis'ma v Zhurnal Fizika Elementarnykh Chastits i Atomnogo Yadra, 2009, No. 1 (149), pp. 81–96.

PHYSICS OF ELEMENTARY PARTICLES AND ATOMIC NUCLEI. EXPERIMENT

Program of Polarization Studies and Capabilities of Accelerating Polarized Proton and Light Nuclear Beams at the Nuclotron of the Joint Institute for Nuclear Research

S. Vokal[a], A. D. Kovalenko[a], A. M. Kondratenko[b], M. A. Kondratenko[b], V. A. Mikhailov[a], Yu. N. Filatov[a], and S. S. Shimanskii[a]

(i) investigate *pp*, *pd*, *dd*, p^3He, d^3He, ^{3}He^{3}He collisions with polarized beams, which will allow one to solve the puzzles of the spin structure of nucleons and lightest nuclei and elucidate the specific features of the spin structure of interaction in the region of nonperturbative QCD; it is especially important that it will be possible for the first time to study the interaction of polarized nuclear matter whose properties may determine the structure of the core of massive stars with great magnetic fields;

(ii) elucidate the nature of strong polarization effects in *NN* interactions at $p_{lab} > 6$ GeV in the region of limiting large p_T, which has not been explained yet, and find out how these specific features are related to the change of behavior of valence quarks in this kinematic region; the availability of polarized nuclei at a collider will allow one to study the complete isotopic set of states of nucleon–nucleon system (*nn*, *pn*, and *pp*) for the first time;

(iii) study in detail the problems of *P* and *T* parity violation in *NN* interactions;

(iv) solve the problem of the nature of cumulative (subthreshold) processes;

(v) elucidate the nature of quark counting rules violation and determine the region of their applicability (including at interaction of lightest nuclei);

(vi) solve the puzzle of resonance behavior of color transparency at $p_{lab} \sim 9.5$ GeV/c ($p_T \sim 2$ GeV/c).

NN Elastic scattering with polarized deuteron beams :

$$p\uparrow + p\uparrow \rightarrow p\uparrow + p\uparrow$$ for calibration

$$p\uparrow + n\uparrow \rightarrow p\uparrow + n\uparrow$$

$$n\uparrow + n\uparrow \rightarrow n\uparrow + n\uparrow$$

} New data!

By the way we will have the counting rules verification!

pd, nd and dd – too!

Exclusive NN study at $x_T \sim 1$

$$N\uparrow + N\uparrow \to BB + MM$$

B (p,n,Λ,Δ...), M (π, K , ...)

Mechanisms of hyperons polarization

$$N\uparrow N\uparrow \to NN$$

The counting rules and isotopic symmetry studies, $p_T \sim 2$ GeV/c anomaly

$$N\uparrow N\uparrow \to BB + \pi\pi(KK)$$

$$N\uparrow N\uparrow \to \Delta\Delta$$

Detail vertexes studies and spin structure of the interaction vertex:

$$q + (q) - (quark - quark)$$

$$q + (qq) - (quark - diquark)$$

$$(qq) + (qq) - (diquark - diquark)$$

DIQUAKS

arXiv:2109.12025v1 [hep-ph] 24 Sep 2021

***Physics of Atomic Nuclei*, Vol. 85, No. 2, 2022**

Qualitative analysis of proton inelastic scattering for diquark searching

Vladimir V. Bytev,[a1] Stepan. S. Shimanskiy[a]

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Abstract

In this paper we discuss exclusive reactions which analysis can be used to receive direct indication of diquark existence. We make estimations of diquark scattering process measurement in inelastic proton-proton collisions. It was shown that putting special restrictions over kinematics and particles in final state of process it will be possible to enhance potential diquark contribution to scattering up to 10^4.

We put qualitative characteristics of process with diquark and ways to distinguish it from quark scattering in model-independent way.

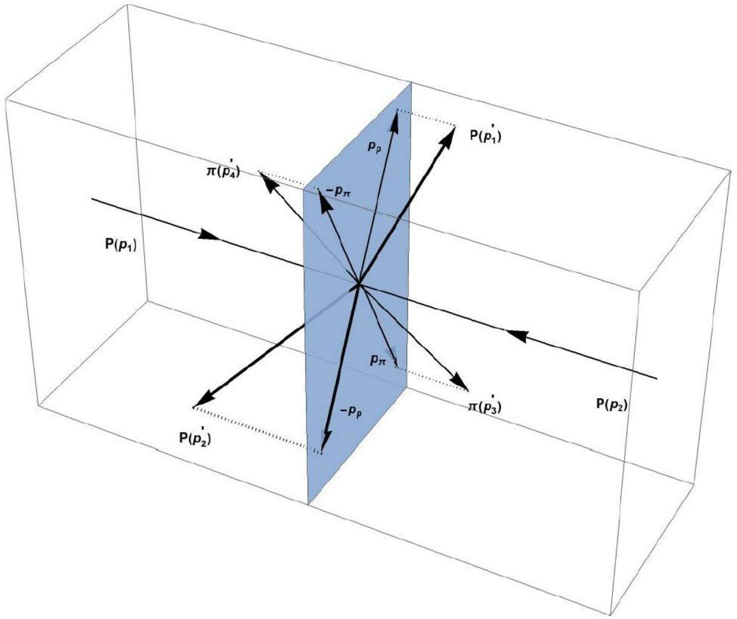


Figure 4: Kinematics of particles in pp collision in the case of diquark-diquark scattering.

High p_T exclusive reactions -> MPI

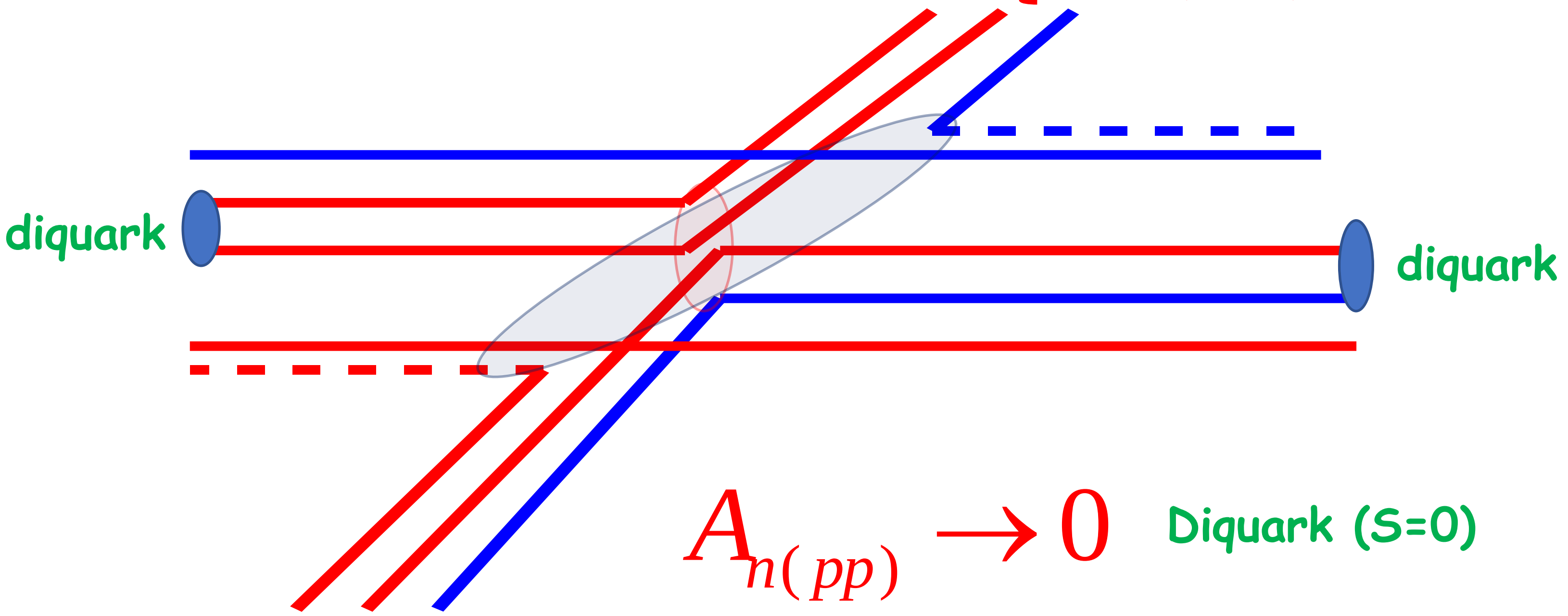
$$\frac{d\sigma(pp \to pp\pi^0\pi^0)}{d\sigma(pp \to pp\pi^+\pi^-)} \approx \frac{12}{7} \approx 1.7$$ With uu and ud diquarks

$$p\uparrow + p\uparrow \to B + B + M\overline{M}$$

$$p\uparrow + p\uparrow \to p + p + \pi^0\pi^0(\pi^+\pi^-)$$

$$R = \frac{N(\pi^+\pi^-)}{N(\pi^0\pi^0)} = \frac{2}{7}$$ Without diquark

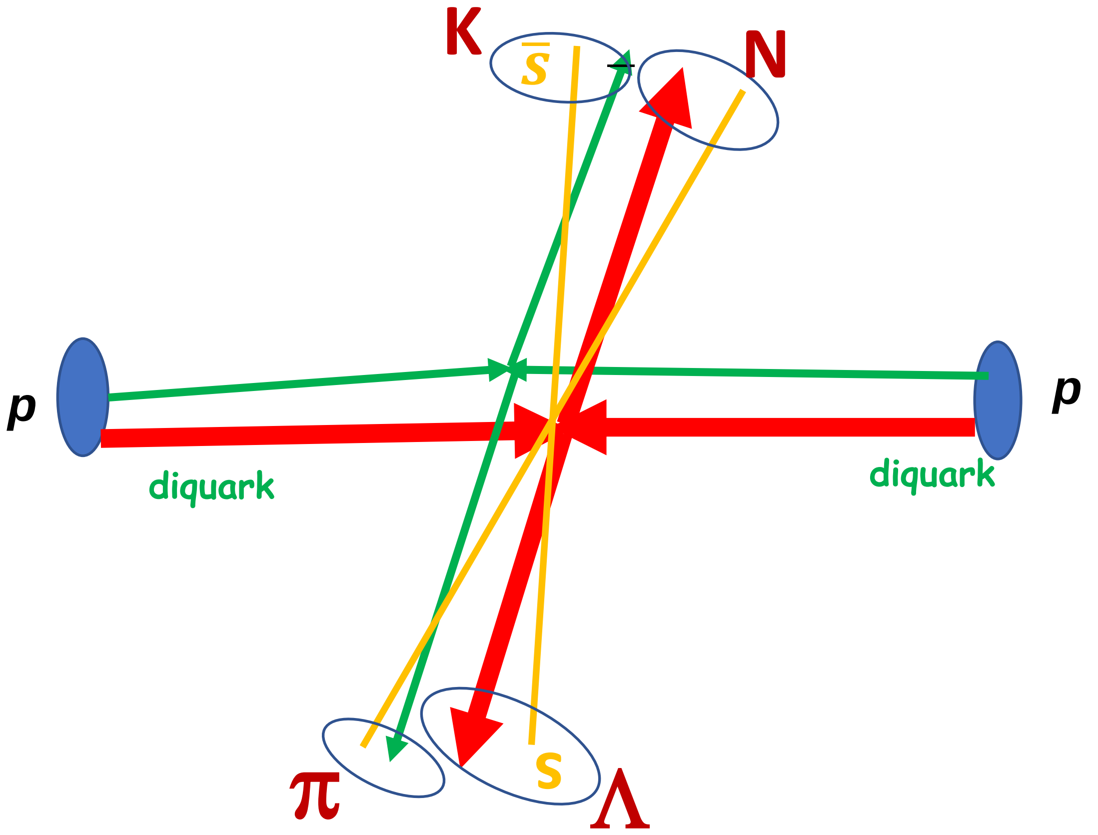
$$R = \frac{N(\pi^+\pi^-)}{N(\pi^0\pi^0)} \to 0$$ Diquark ud only



$$A_{n(pp)} \to 0$$ Diquark (S=0)

High p_T exclusive reactions -> MPI

$p + p \to \Lambda\pi + KN \ (\pi K + \Lambda N)$



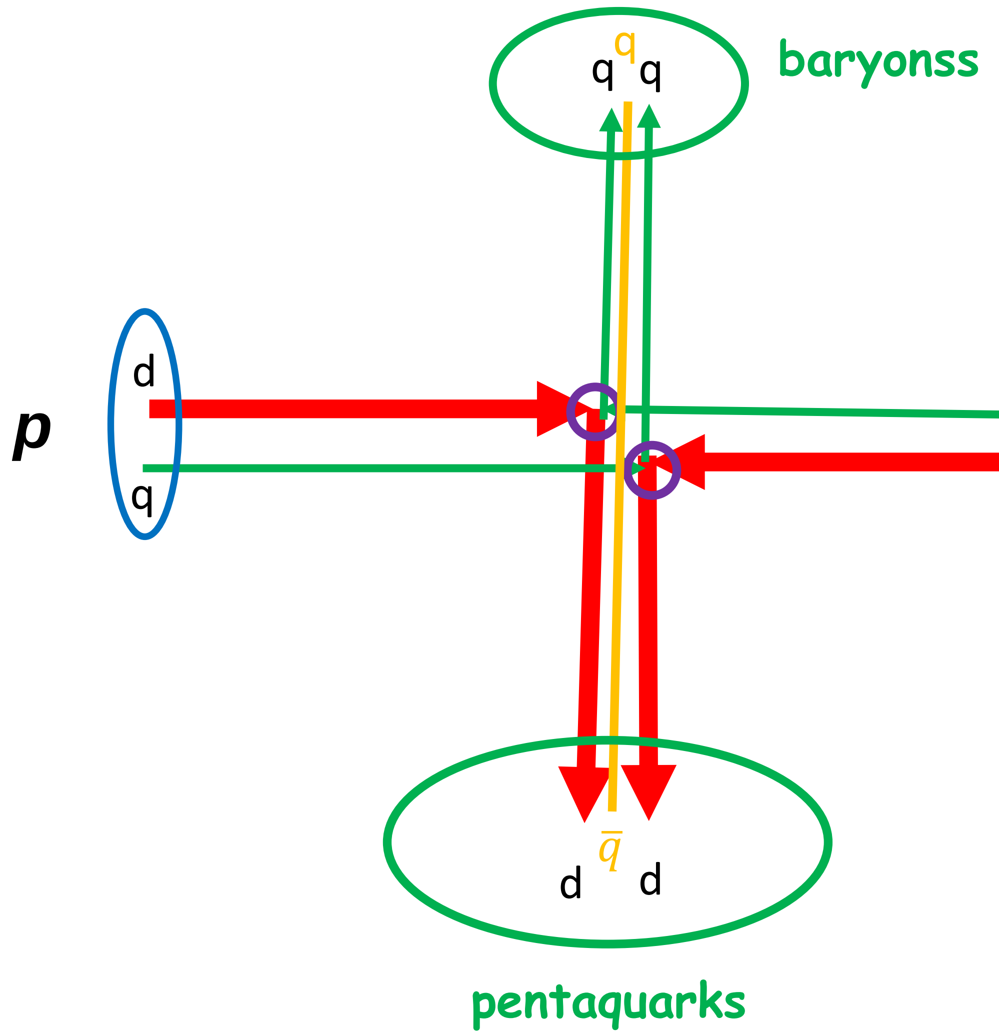
Ya.I.Azimov, PNPI Winter School 2013

Status of the pentaquark problem

- 1st relatively certain theoretical suggestion
  of mass ~1530 MeV and width < 15 MeV :
  Diakonov, Petrov, Polyakov, Z.Phys., A**359** (1997) 305.
- Experiment : about ten papers with positive evidences;
  about ten papers with negative results
  (some of them with higher statistics).
- Common opinion and PDG position
  (since edition of 2008) :
  Pentaquark is dead !
  (Note, at the same time, great enthusiasm
  in searches for tetraquarks !)

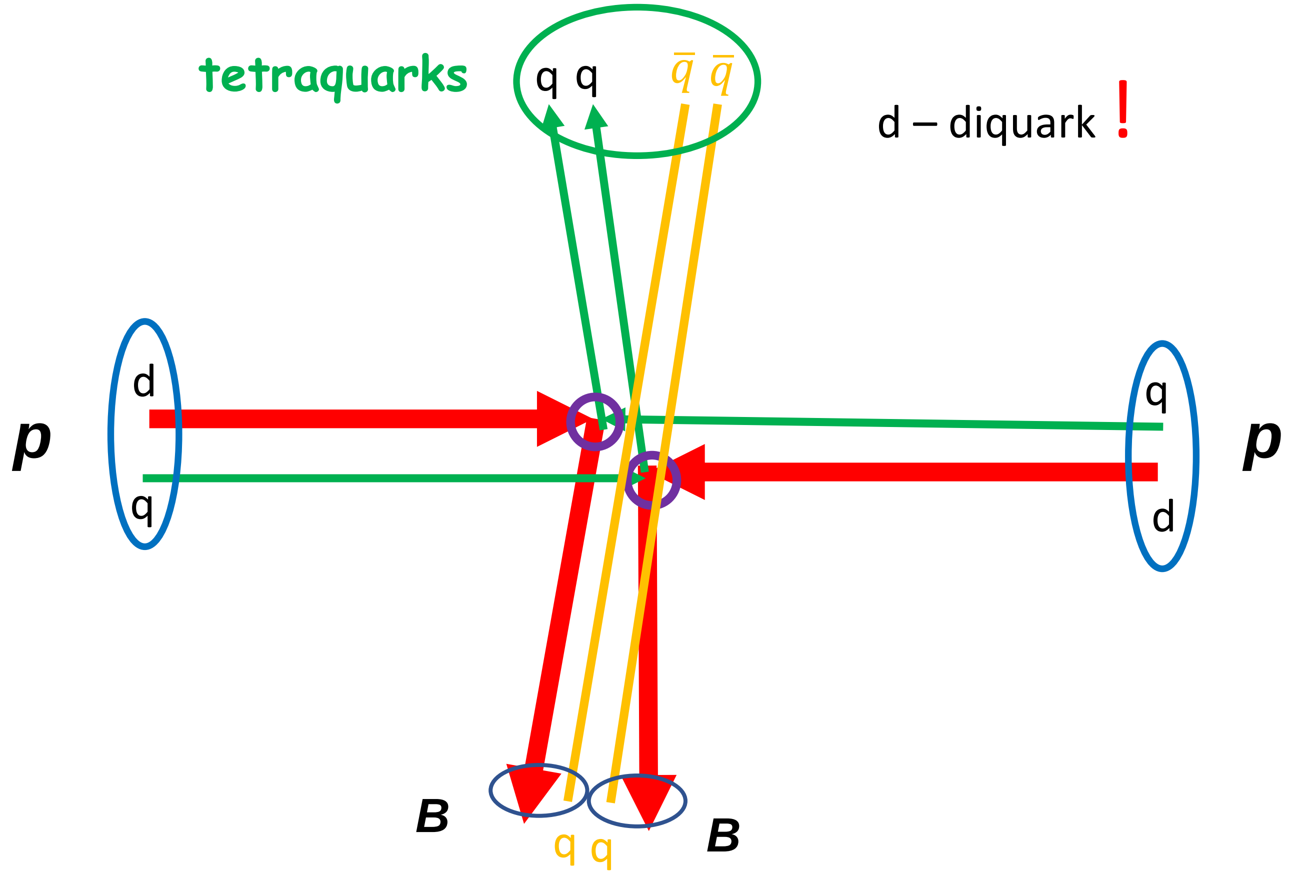
Exotic states production

pp - reactions with direct pentaquarks production



Exotic states production

pp - reactions with direct tetraquarks production



Thank you for attention

Color Transparency

arXiv:1208.3668v1 [nucl-th] 17 Aug 2012

Gerald A. Miller

Physics Department, Univ. of Washington, Seattle, Wa. 98195-1560, USA

Abstract. Color transparency is the vanishing of nuclear initial or final state interactions involving specific reactions. The reasons for believing that color transparency might be a natural consequence of QCD are reviewed. The main impetus for this talk is recent experimental progress, and this is reviewed briefly.

The basic idea is that some times a hadron is in a color-neutral point-like configuration PLC. If such undergoes a coherent reaction, in which one sums gluon emission amplitudes to calculate the scattering amplitude, the PLC does not interact with the surrounding media. A PLC is not absorbed by the nucleus. The nucleus casts no shadow. This is a kind of quantum mechanical invisibility.

Progress in Particle and Nuclear Physics 69 (2013) 1–27

Review

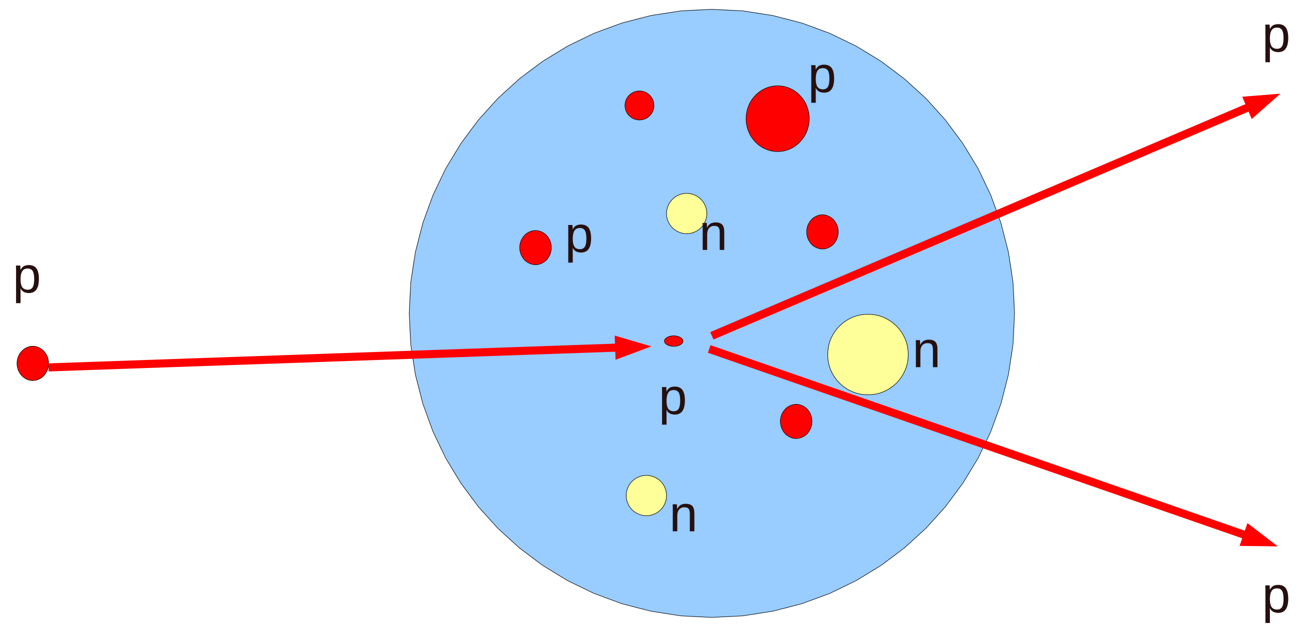
Color transparency: Past, present and future

D. Dutta [a,*], K. Hafidi [b], M. Strikman [c]

Color(nuclear) transparency in 90^0 c.m. quasielastic $A(p,2p)$ reactions

The incident momenta varied from 5.9 to 14.4 GeV/c, *corresponding to* 4.8 $< Q^2 <$ 12.7 $(GeV/c)^2$.

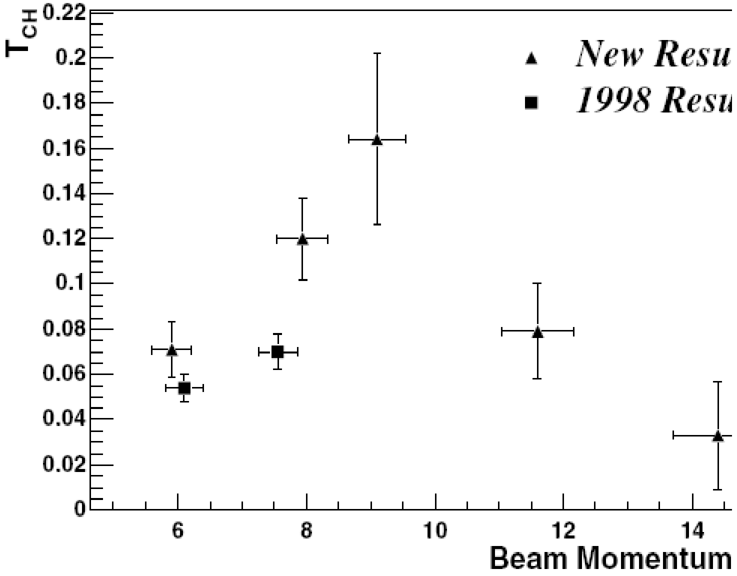
$$T = \frac{\frac{d\sigma}{dt}(p + "p" \rightarrow p + p)}{Z\frac{d\sigma}{dt}(p + p \rightarrow p + p)}$$



VOLUME 87, NUMBER 21 PHYSICAL REVIEW LETTERS 19 NOVEMBER 2001

Energy Dependence of Nuclear Transparency in C(p,2p) Scattering

A. Leksanov,[5] J. Alster,[1] G. Asryan,[3,2] Y. Averichev,[8] D. Barton,[3] V. Baturin,[5,4] N. Bukhtoyarova,[3,4] A. Carroll,[3]
S. Heppelmann,[5] T. Kawabata,[6] Y. Makdisi,[3] A. Malki,[1] E. Minina,[5] I. Navon,[1] H. Nicholson,[7] A. Ogawa,[5]
Yu. Panebratsev,[8] E. Piasetzky,[1] A. Schetkovsky,[5,4] S. Shimanskiy,[8] A. Tang,[9] J. W. Watson,[9]



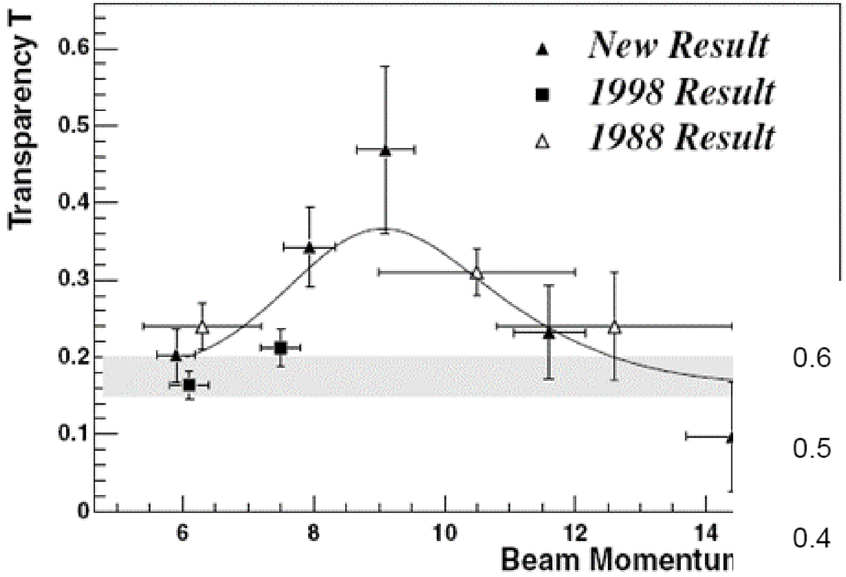
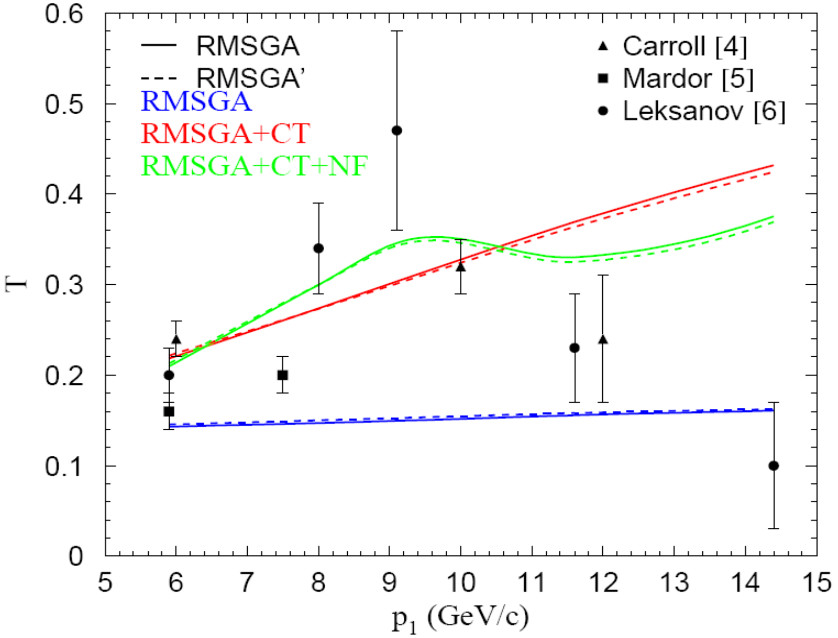


FIG. 2. Top: The transparency ratio T_{CH} as a function of the beam momentum for both the present result and two points from the 1998 publication [3]. Bottom: The transparency T versus beam momentum. The vertical errors shown here are all statistical errors, which dominate for these measurements. The horizontal errors reflect the α bin used. The shaded band represents the Glauber calculation for carbon [9]. The solid curve shows the shape R^{-1} as defined in the text. The 1998 data cover the c.m. angular region from 86°–90°. For the new data, a similar angular region is covered as is discussed in the text. The 1988 data cover 81°–90° c.m.

B.Van Overmeire, J.Ryckebusch, nucl-th/0608040



PANDA $\bar{p}p$ studies at $x_T \sim 1$

$$\bar{p}p \to \bar{p}p$$
$$\bar{p}p \to \bar{n}n - ?$$

The counting rules and isotopic symmetry studies, $p_T \sim 2$ GeV/c anomaly(?)

$$\bar{p}p \to \bar{p}p + \pi\pi(KK)$$
$$\bar{p}p \to \bar{\Lambda}\Lambda + KK(\pi\pi)$$
$$\bar{p}p \to B\bar{B} + l^+l^-$$
$$\bar{p}p \to M\bar{M} + l^+l^-$$
$$\bar{p}p \to l^+l^- + l^+l^-$$

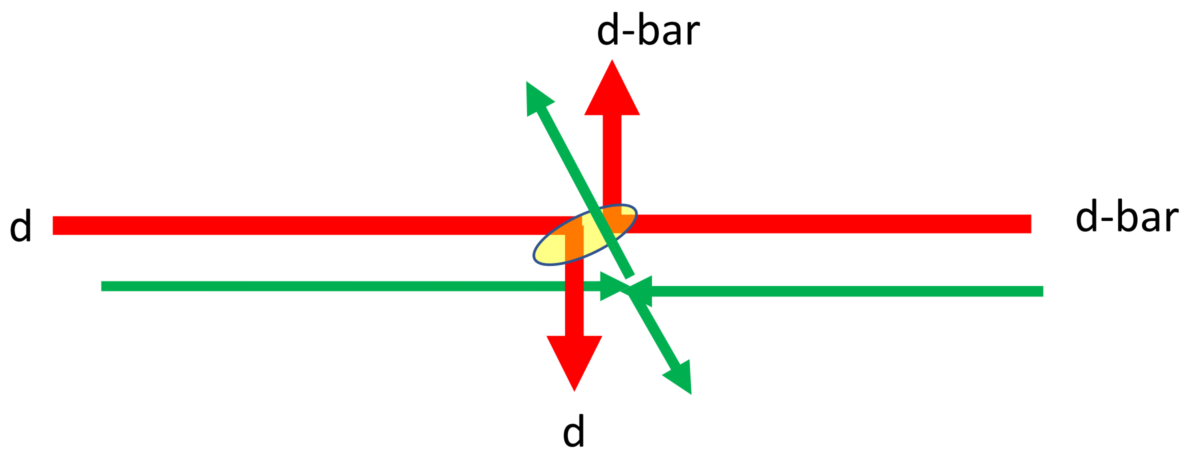
Detail vertexes studies:

$$q(\bar{q}) + \bar{q}(q) - (quark - antiquark)$$
$$q(\bar{q}) + \overline{qq}(qq) - (quark - antidiquark)$$
$$qq + \overline{qq} - (diquark - antidiquark)$$

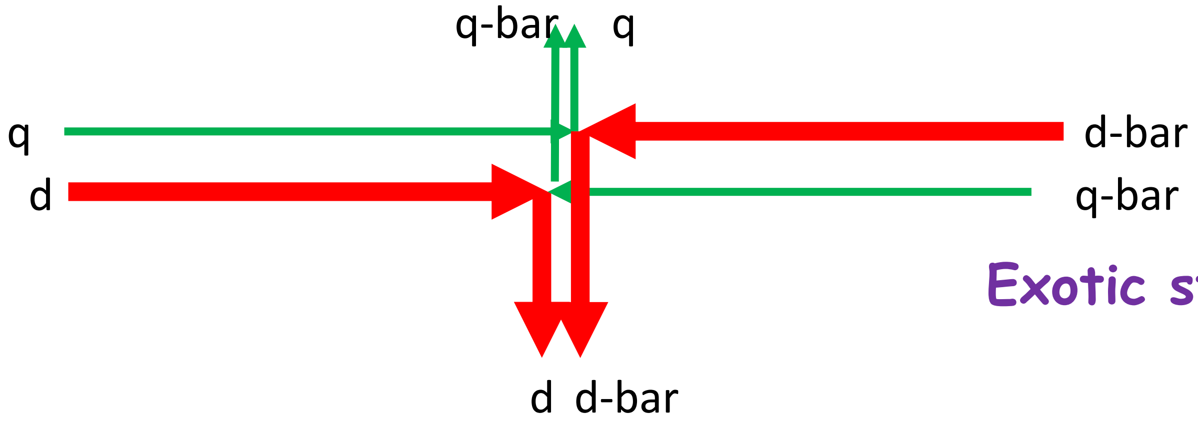
Скачок в сечении упругого рассеяния?

PANDA

Direct reaction to tetraquarks production in $\bar{p}p$



Diquark proof

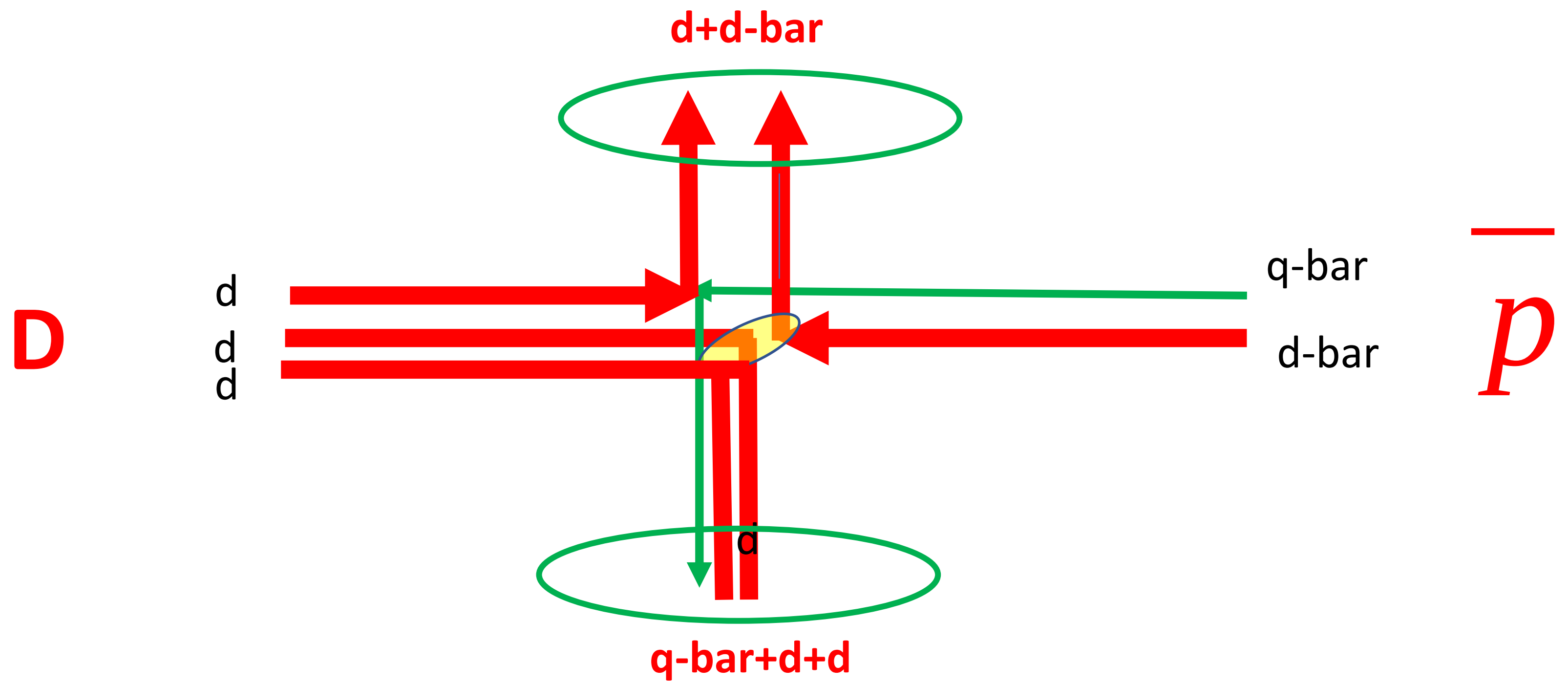


Exotic states production

PANDA

Exotic states production

$\bar{p}d$ - reaction with tetraquarks +pentaquark production



PETERSBURG NUCLEAR PHYSICS INSTITUTE NAMED BY B.P. KONSTANTINOV
Petersburg Nuclear Physics Institute
OF NATIONAL RESEARCH CENTRE «KURCHATOV INSTITUTE»

Study of feasibility to detect pentaquark $\Theta^{+}(\bar{\Theta}^{-})$ in PANDA

S.Belostotski, S.Manaenkov, V.Petrov, D.Veretennikov

PANDA collaboration meeting 19/3,
November 4-8, 2019, GSI